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TECHNICAL MANUAL

VOICE/DATA TELEPHONE SYSTEMS

HEADQUARTERS, DEPARTMENT OF THE ARMY
APRIL 1989

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No. 5-811-9

HEADQUARTERS
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VOICE/DATA TELEPHONE SYSTEMS

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CHAPTER 1

GENERAL

1-1. Purpose. This manual is a general guide to establisdh the criteria for the design of Private Branch Exchange (PBX) type telecommunications systems for Department of the Army installations, including individual buildings or groups of buildings, in Continental United States (CONUS) areas only. This manual is not intended to address the requirements or criteria for the designing of a post wide communications network.

1-2. Scope. This manual outlines the general engineering standards and principles applicable to the design of a totally operational telecommunications system, both inside and outside plant. This manual is not intended for use in designing any associated systems which may interface with a telecommunications system such as a Local Area Network or non-telephone based intercom system. Where special conditions and problems are not specifically covered in this manual, acceptable industry standards should be followed. Modernization of existing telecommunications facilities solely for the purpose of meeting criteria in this manual is not required. The criteria contained herein are not retroactively mandatory. This manual complements other Army criteria and the National Fire Protection Agency (NFPA) 70.

1-3. Design process. The criteria provided in this manual are to be used by the designer to satisfy the telecommunications requirements defined during the planning stage. The design process should include at least two milestones, each of which should normally culminate into two formal submissions and design reviews. The milestones are preliminary design and final design.

a. Preliminary design. In summary, the preliminary design process includes the initial survey efforts and data gathering necessary to determine the required configuration of the new system. If the project involves expansion of an existing system, this phase will also include the efforts necessary to determine the condition, ownership and expansion capabilities of the existing system. This information should be used to develop a preliminary design which generally depicts the overall approach and concepts that the designer proposes to include in the project. This design should be reviewed to determine if all of the new system requirements are being satisfied. Normally, it is best to conduct this review at the 30 or 45 percent completion level of the project.

b. Final design. The results of the preliminary design review will be used to develop a final design which includes a complete description of the new system along with the associated drawings and specifications. To help insure continuity and to simplify the review process, the communications symbols shown in figure 1-1 or in American National Standards Institute (ANSI) Y 32.9 should be used. For symbols other than communication related, refer to Air Force Technical Order (AFTO) 31W3-10-22/Army Field Manual (FM) 11-486-5. The designer should insure that telephone symbols do not conflict with symbols used on other drawings. This design should be reviewed at the 100 percent stage and revised where necessary. The type of submittals required should be based upon the scope and complexity of the project and the following specific components:

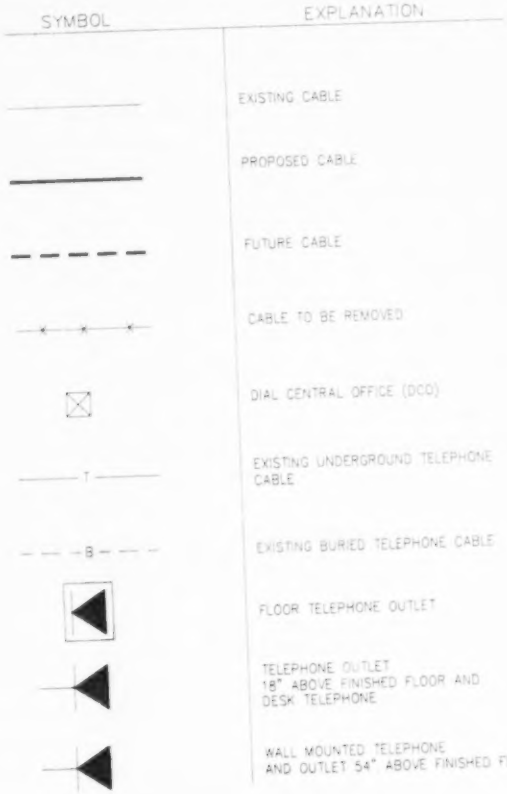

Figure 1-1.—Communication symbols.

(1) Outside cable. In general, if multiple buildings are involved or if significant changes are required to outside plant cabling, a site plan showing the existing and proposed routing will be necessary. The designer should also indicate other utilities on the site plan in order to demonstrate the degree of difficulty of any proposed construction and to avoid unnecessary disruption during the construction process. If manhole and conduit systems are to be used or built, the drawings must clearly indicate the duct routing of existing and proposed cables and specify the placement of any new ducts or manholes. If existing ducts are going to be used to install new cables, the designer should verify and reserve duct availability for each proposed cable with the proper post authorities and indicate the duct assignment on the drawings. This may require the actual rodding of the ducts to insure they are unobstructed.

(2) Interior equipment and cable. Drawings should be

provided for all interior equipment and cable layouts, including equipment rooms, switching systems, racks, and frames. Building cable entrances should be clearly shown. In addition, details should be provided which indicate the proper placement of equipment, backboards, punch-down blocks, splicing racks and cable racks. The drawings should also include cable routing diagrams describing how the various areas will be connected to the necessary equipment. If new inside wiring, telephone sets, or data terminals are included in the project, location drawings will be necessary so that the contractor will know where to place the communications outlets and equipment. These drawings, which can be developed from layouts of the building, will show the routing of telephone cable and the location of all telephone sets, data terminals, and jacks. A trunking diagram should be provided to indicate the required trunking arrangement between the PBX and base Dial Central Office (DCO), local operating company, or host switching equipment.

1-4. References and list of terms. Appendix A contains a list of references used in this manual and the Glossary contains the explanation of terms and abbreviations used in this manual.

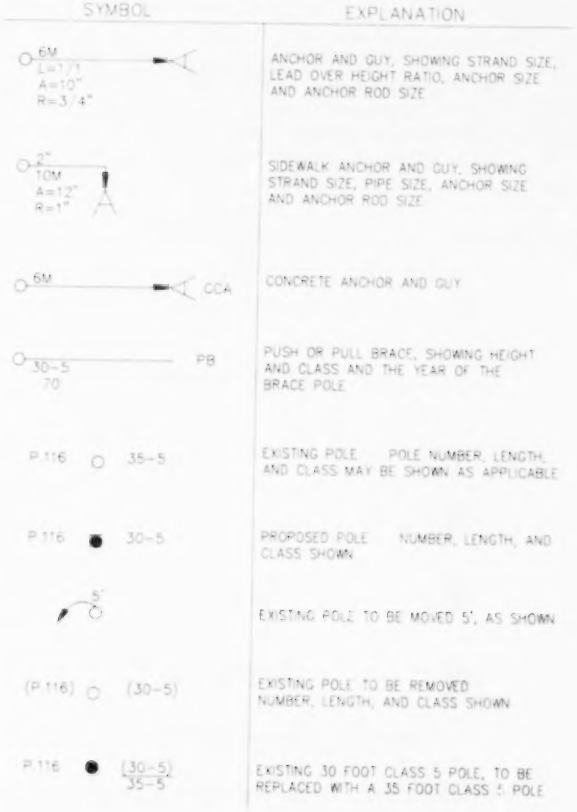

Figure 1-1.—Communication symbols continued.

SYMBOL
EXPLANATION
MH16
4 MCD
810' WW
MH1626
UNDERGROUND CONDUITS AND MANHOLES, SHOWING MANHOLE NUMBERS AND THE WALL TO WALL (WW) DISTANCE BETWEEN THEM. FOUR MULTIPLE CLAY DUCTS ARE SHOWN
BKTA-1
1-100
100 PR
H88
1-100
100-662 COILS
100-PAIR LOADING COIL CASE EQUIPPED WITH (E/W) 100 H-88 COILS, PAIRS 1-100 LOADED
169'
POLE LINE SHOWING CENTER-TO-CENTER SPAN DISTANCE
EXISTING MANHOLE, WITH COVER VISIBLE
MH1028
MANHOLE (MH), HANDHOLE (HH), OR PULL BOX (PB), SHOWING ASSIGNED NUMBER
TYPE A
12' x 5' x 6'-6"
PROPOSED MANHOLE. THE DIMENSIONS ARE SHOWN AS LENGTH x WIDTH x HEADROOM AND ARE THE INSIDE MEASUREMENTS. TYPE OF MANHOLE IS ALSO SHOWN

Figure 1-1.—Communication symbols continued.

CHAPTER 2

DESIGN CONSIDERATIONS

2-1. Purpose. Before beginning the detailed design process, two fundamental questions or issues should be addressed in order to establish the basic approach for the new system, and essentially serve as the foundation for the entire project. Normally it will be necessary to analyze a number of different design alternatives from an economic, maintenance, performance and appearance perspective. These issues include:

a. Outside plant. The use of direct buried cable, underground conduit and cable, and aerial cable.

b. Switching equipment. The use of distributed or centralized switching.

2-2. Existing systems, facilities, and conditions. Before the various design approaches can be properly addressed, a clear understanding must be established of the existing network, equipment, cable facilities and capabilities of the network, with which the new system will interface. Also, the general environment and conditions in which the new system will be constructed and operated must be considered.

2-3. Switching system interface. For access to the public switched network the switching equipment portion of the system will interface with either the post DCO or the local telephone company. Each situation requires a different design approach and different considerations. If the switching equipment is to interface with a post DCO, the potential use of a remote switch should be investigated. In addition, the type of trunks which are to be interfaced must be identified.

2-4. New system requirements. Ideally the requirements should be clearly defined during the planning process and provided in sufficient detail to allow performance of the design analysis and identification of the best overall approach. However, before proceeding, a quick review should be performed to insure that these telecommunication requirements are clearly defined. Some of the major issues which sometimes cause misunderstanding are briefly covered in this chapter; hopefully if they are used as a checklist, unnecessary confusion can be avoided.

a. Voice circuits. Voice circuits are often referred to as both trunks and lines, which can cause some confusion especially if the user is only familiar with key type systems. In general, lines are used to connect people to equipment and trunks are used to connect equipment to equipment. Where practical, the designer should attempt to stay with this convention. Almost everything included in the design is a function of lines required therefore, it is imperative that this parameter be accurately defined. If not otherwise provided, the following criteria can be used as a general guide. The figures are based upon the square footage of the building and the type of administrative functions performed. It is stressed that they do not include data requirements nor is the guide applicable to nonadministrative functions.

Area Usage	*Lines/1000 sq ft*
Executive	8 to 12
Technical	7 to 10
Secretarial	6 to 8
Clerical	5 to 7

To accurately design the system in a new facility the designer should contact the prime Architect/Engineer to obtain floor plans and then discuss the functions with the administrative staff of the facility.

b. Data circuits. Many organizations are using telephone lines to transmit data. While today's PBX's are designed to accommodate this requirement, it is not normally advisable to route permanent point-to-point data circuits through the PBX as this can degrade the performance of the system. An exception to this is when the switch is to be used to facilitate modem pooling, protocol conversion, or serve as an integral part of the data network. While the use of a digital PBX allows data circuits to be switched, just as voice circuits, a non-blocking PBX should be considered if data transmission demands are expected to be significant. To eliminate the chance of blocking, a non-blocking PBX provides unique paths for all line and trunk circuits thereby preventing the possibility of a line being denied access to another available line or trunk. In general, if a data connection is to be of a constant nature, it should be excluded from the design. However, if the requirement is to be intermittent or switched, it should be clearly identified and included.

2-5. Outside plant considerations. With many designs, outside plant considerations will be minimal as the objective is to design a PBX and the associated inside plant; however, if the new system requires outside plant or modifications to the existing outside plant, a plan must be developed detailing how direct buried, underground or aerial cable will be used. Many systems will incorporate the use of all of these construction techniques; however, normally one method will predominate. Each method has advantages and disadvantages and is particularly suited for specific applications.

a. Underground cable. If space in ducts is available in an existing conduit/manhole system, underground cable in conduit is the preferred approach. This method is usually more economical and less disruptive to the surrounding environment than other methods of cable placement. Additionally, major routes that are likely to experience frequent change or growth are likely candidates for underground conduit. Cables in the immediate vicinity of the post central office are often placed in underground conduit and manhole systems to simplify access for maintenance and expansion. However, if duct space in an existing conduit/manhole system is not available, implementation of a new conduit/manhole system should be specified only if there is a definite need or requirement that cannot be satisfied with direct buried cable or aerial cable. The reason for this approach is the significant cost of con-

struction of a new conduit/manhole system. Also, with the high initial construction cost these systems should always be sized to accommodate a growth of at least 100 percent.

b. Direct buried cable. In most situations, if underground cable is not applicable, direct buried cable will be the preferred approach. Although direct buried cable would not be as secure as underground cable, it is less susceptible to environmental damage from forces such as lightning, requires less maintenance, is usually more economical to construct, and is more pleasing aesthetically than aerial cable. It is especially useful for routes which are not likely to require frequent expansion or replacement. The major disadvantages of direct buried cable plant are:

The cable is exposed to damage from rocks and debris during construction. However, with proper construction techniques this should not present problems.

The cable may experience possible future damage resulting from below ground construction along the cable route.

Expansion or replacement is difficult. However, the effect of this limitation can be mitigated with the proper access points such as pedestals, cross connect boxes, and handholes.

c. Aerial plant. In some situations where aerial plant is already in use or electric pole lines are available, the use of aerial plant should be investigated to determine if it is economically advisable. However, it should be remembered that aerial plant may be more expensive even with existing pole lines. This is due to the need to change out poles for load handling requirements and relocating existing utilities to provide the necessary road clearance and satisfy the electrical clearance requirements of the NFPA 70 and ANSI C2. Aerial plant is sometimes useful in areas that have difficult soil conditions (rocky or marshy) and when installing cable in rough or hilly terrain. In addition, it can be very helpful when installing cable in areas that are already congested with underground utilities. In general it should be realized that the design of aerial plant pole lines is a rather complicated art, especially when the various NFPA 70 and ANSI C2 requirements and vehicular traffic requirements are considered; therefore, aerial plant should only be used if there is a specific need that cannot be satisfied with underground or direct buried cable.

2-6. Analysis of distributed switching. With the decreasing cost of computing power in relation to the cost of installed cable, it is often economically advisable to utilize a small remote switch (or a number of remote switches) as opposed to a single large centralized switch. This concept is referred to as distributed or remote switching. Normally, it is used in conjunction with a host switch, which performs much of the initial call processing and houses the user data base. The remote switch can be connected to the host via physical copper circuits, T-carrier, or a fiber optic system. In Department of Defense (DoD) networks, fiber optic systems should be the predominate choice to link the remote and host switch. Typically the distributed switching concept is only applicable in larger networks that encompass a relatively wide area. It is also likely to be more beneficial if the users tend to be concentrated in nodes. Economically the concept is cost effective by reducing the amount of cable that must be installed over relatively long distances. It also can increase the quality of signal transmission (data and voice) as the signals are transmitted digitally between the host and remote switch and the analog station loops are much shorter. However, the initial equipment costs of a remote switch/host switch arrangement is almost always more expensive than a single large central switch with the same number of lines. The remote switch is only beneficial when the decreased cable costs offsets the additional cost of a distributed switching system. Remote switches also offer the advantage of easier accommodation of growth and, in some cases, additional system redundancy. Utilization of T-carrier or fiber optics to perform trunking between the host and remote switches allows additional capacity to be added at a later date. Also, many remote switches can continue to process calls within their respective nodes after the host switch becomes inoperative. In addition, some remote switches can be equipped with alternate trunks to the outside world. With this capability the remote switch can be used to contact the outside world even if the trunks to the host switch are severed or become inoperative. In general, remote switches should not be considered for small installations with less than 200 lines. If the system has 200 lines or more and an area or node can be identified that contains more than 30 percent of the lines, it is probably advisable to investigate the economic merits of remote switching; the concept is more applicable in multiple building applications. In addition, the use of remote switching should always be investigated when a new building is being added to a post that is already equipped with a digital central office (CO) or PBX. The manufacturer of the existing switch should be contacted to determine if remote switches are available and investigate the changes necessary to implement the host/remote switching concept.

3-1. General. The inside plant portion of the design normally constitutes the focal point of the telecommunications system and generally includes the switching system, the inside wiring, telephone sets, data sets, the system's software programs, and all support hardware including frames, racks, and power systems. Inside plant equipment may also include T-carrier or fiber optic systems. When designing the inside plant it must be remembered that this portion of the system will interface directly with building occupants and therefore safety is a primary concern. Electrical codes and requirements concerning grounding and protection must be followed rigidly. The designer must insure that the system can be economically maintained and can be easily expanded, within normal growth limits (typically 50 percent). The system should also accommodate the requirements of any future adjacent buildings that are planned in the next five years. The design must also identify the support requirements for the telecommunications system such as air conditioning, electrical power, backup power, fire protection, and suitable, secure building space.

2. Switching equipment. Modern switching systems can normally be classified as PBX type switches or electronic key systems (EKS). While the digital PBX is the preferred technology as it allows the greatest flexibility and provides enhanced features, EKS often prove cost-effective and are functionally appropriate for applications with less than 20 stations.

a. PBX architecture. The PBX should employ stored program control architecture using digital pulse code modulation (PCM) and time division multiplexing (TDM). The quantizing process used in the PCM should conform to the Mu 255 coding scheme of eight bit PCM words as defined by the Federal Communications Commission (FCC) Rules, Part 68, and the International Telegraphy and Telephone Consultative Committee (CCITT) Recommendation 8.711. The stored program control system should automatically reload and reboot the switch in the event of a complete power failure.

b. Control processor. A single common control processor will be sufficient for most operations, as these processors are extremely reliable. In some strategic operations it may be necessary to consider the use of dual or redundant processors; however, this requirement should be identified to the designer. The control programs should be developed in a language which is user oriented and provides sufficient menus and prompts which allow a technician to easily learn to modify the major performance characteristics of the system such as trunk routing, translation actions such as deletes and prefixes, line assignments, and class of service. These programs must also provide maintenance diagnostic routines which operate continuously and immediately print out a description of any fault on a video terminal or maintenance printer terminal.

3-3. System features. The following is a brief description of the typical PBX standard and optional system features. The designer should note that while the features listed as standard are typically standard, only the specific features required for each application should be included in the design. This practice will eliminate the chance that the government will pay extra for any non-required or non-essential features.

a. Standard features.

(1) *Attendant camp-on with tone indication.* This feature allows an attendant to hold an incoming call in specific waiting mode when a desired station is busy and send a camp-on tone indication to the busy station. When the busy station becomes idle, it is automatically rung and connected to the waiting party. Camp-on warning tone is heard only by the internal station. Music on hold may be provided to the waiting party.

(2) *Attendant loop release.* This service enables an incoming console loop to become available for another incoming call as soon as the attendant directs the first call to a station even if the station does not answer.

(3) *Attendant override.* This service feature allows an attendant to enter a busy trunk or line connection. A warning tone will be heard by the connected parties, after which the connected parties and the attendant will be connected in a three-way connection.

(4) *Automatic recall.* This service allows the system to direct each call processed by the attendant which has exceeded a programmed duration in hold to recall the console.

(5) *Busy lamp field (BLF).* The PBX console is equipped with a BLF which provides visual indications of busy or idle station conditions for all lines selected by the attendant.

(6) *Busy verification.* This service feature allows an attendant to determine whether the station is busy or has been placed in line lockout.

(7) *Call back.* This feature allows a calling station, upon encountering a busy station, to have his call automatically completed when the called station becomes idle.

(8) *Call forwarding — all calls.* This feature allows the station user to forward all calls directed to the station, to a designated station, or to the attendant.

(9) *Call forwarding — busy line.* This service feature permits a call to be immediately forwarded to another designated station or to the attendant when the called station is busy.

(10) *Call forwarding — don't answer.* This feature permits calls to unattended stations to be forwarded to a designated station or to the attendant after a programmed ringing interval.

(11) *Call forwarding — intercept/announcement.* This feature allows incoming stations and trunks to connect to the attendant or an announcement device if a vacant or unassigned number is dialed.

(12) *Call forwarding — override.* This feature permits, by class of service, a secretary station to ring preselected stations which have set up call forwarding — all calls. This feature can also be used for call screening purposes.

(13) *Call hold.* This feature allows station users to place on hold any call in progress, freeing their line to initiate a second call, or perform a second feature.

(14) *Call pick-up — group.* This feature allows a station to intercept a call directed to another station within its group. The ringing station number need not be dialed.

15) *Call queuing.* This feature directs all calls to the console to be placed in a First-In/First-Out queue. The attendant may answer these calls in the order of their arrival by depressing the "answer" key.

(16) *Call transfer — attendant.* This feature allows station users to transfer established calls to the attendant for further processing.

(17) *Call waiting.* This feature allows a busy station to receive a second incoming call. The
busy station, upon receiving the second incoming call will hear a camp-on tone. The busy station can place the existing call on hold to answer the incoming call. The station can then alternate between both calls.

(18) *Class of service — individual.* All the stations can be provided with a class of service on a per station basis. The class of service is assigned to each station to specify the customer group assignment, determine the proper authorization and restriction in service features and trunk access and to provide proper control in the switching system depending on the type of telephone set, pushbutton or rotary dial type. The class of service is categorized into three fields. Each station must be assigned one each of the following class assignments.

—Telephone class

—Trunk restriction class

—Service restriction class

(19) *Data line security.* Circuits used for data transmission may be protected from intrusions, such as camp-on, busy verification, executive right of way and attendant override by class of service programming.

(20) *Data transparency.* When a digital data interface unit is equipped, all ASCII data communications paths are transparent to terminal and computer equipment.

(21) *Day/night class of service.* Station class of service can be automatically altered when the system is in the night mode.

(22) *Dial access to attendant.* This feature allows a station to access the attendant by dialing the operator call code.

(23) *Digital display — trunk.* Trunk information including trunk number, route, and termination data is displayed on the console for incoming and outgoing calls.

(24) *Direct-in termination (DIT).* Incoming trunk calls may be programmed to route directly to preselected stations without attendant intervention. DIT features may be assigned to trunk circuits on a day or night or full time basis. "call-forward" and "Hunt" features may operate in conjunction with DIT.

(25) *Direct inward dialing (DID).* The PBX can offer "Centrex" equivalent service by using the DID feature. Incoming calls are routed directly to an internal station based on digit information received from the serving central office. Flexibility is provided for signalling supervision and received digit translation.

(26) *Direct outward dialing (DOD).* A station user may gain access to the exchange network without the assistance of an attendant by dialing an access code and receiving a second dial tone from the PBX. The user may then proceed to dial the desired exchange or network number.

(27) *Direct T-l interface.* The PBX can be equipped to connect to T-l trunks in a digital network without external hardware.

(28) *Distinctive ringing.* Incoming calls to the station may be identified as external or intra-system by the type of audible signal (on-off duration) provided to the station.

29) *Do not disturb.* The station user may place his station in a Do not disturb condition which excludes all audible signals.

(30) *Executive right of way.* Selected stations, upon encountering a busy station, can bridge into the existing conversation. A warning tone is transmitted to both parties of the existing conversation before the third party enters the conversation.

(31) *Flexible numbering of station.* The PBX can be programmed to fit the requirements of the end user, with regards to a specific station numbering plan.

(32) *Hot line.* This service feature establishes a connection between two specific telephone sets, designated as "Hot line stations", when the calling hot line station user lifts the handset.

(33) *House phone.* This feature allows certain stations to reach the attendant by merely going off-hook.

(34) *Howler tone sending.* This feature causes stations which are left off-hook in an undetermined condition to be sent a distinctive louder than normal tone.

(35) *Incoming call identification.* This feature allows an attendant to identify the type of service or trunk group associated with a call arriving at the console by the visual indication provided for each trunk type.

(36) *Incoming central office call to tie line connection.* This feature allows an attendant to connect an incoming exchange network call, via a tie trunk, to a station at a distant PBX.

(37) *Individual trunk access.* The attendant may access specific trunks within a trunk group by dialing an access code.

(38) *Line lockout.* This feature causes stations which are left off-hook to be released from the system. Service will be restored to the station once the receiver is placed on-hook for two seconds.

(39) *Meet-me paging.* This feature allows a station user to transfer a call to a "Meet-me" circuit for intercept by the desired party.

(40) *Meet-me paging — attendant.* This feature allows the attendant to transfer incoming calls to a "Meet-me" circuit, for intercept by the desired party.

(41) *Miscellaneous trunk access.* This service feature allows a station user or terminating tie line party to originate an outgoing call to such trunk groups as Foreign Exchange

(FX), Wide Area Telephone Service (WATS), and Common Control Switching Arrangement (CCSA).

(42) *Miscellaneous trunk restrictions.* With this feature, selected stations are denied access to specific trunk groups such as FX, WATS, CCSA, exchange network, dictation, paging and other TIE trunks.

(43) *Multiple console operation.* The PBX can be equipped with multiple consoles.

(44) *Multiple line operation.* Individual station lines may appear on electronic multiline sets simultaneously, duplicating the service offered by conventional key sets.

(45) *Night connection — fixed.* This feature provides arrangement to route incoming exchange network calls, normally directed to the attendant, to preselected stations when the attendant positions are placed into the night mode or not attended. These calls answered at the night stations can be transferred to another station within the system by means of Call transfer — All calls.

(46) *Night connection — flexible.* This feature provides arrangements to route incoming exchange network calls, normally directed to the attendant, to any station or stations when the regular attendant position are not attended. These calls answered at the night stations can be transferred to another station within the same system.

(47) *Non-volatile generic program.* A PBX with this feature does not require external power or mechanical storage devices such as cassette tape or floppy disk for memory retention.

(48) *On-line maintenance.* PBX maintenance and data base administration may be performed without removing the system from service.

(49) *Outgoing trunk queuing.* Upon encountering a trunk busy condition for outgoing calls, station users may access a queue for service. The queued station will be automatically called back by the system and connected to the desired trunk when available. If used in conjunction with least cost routing, the system will dial out the stored number when the station answers.

(50) *Paging access.* The PBX can be equipped to access voice paging equipment on a trunk or line level access.

(51) *Paging transfer.* A station user, upon receiving an incoming call, holds the call and pages the wanted party. If the paged party answers, the station user replaces the handset onto the switchhook, which establishes a connection between the paged party and the line on hold.

(52) *Passing dial tone.* When a restricted station requests the attendant to place an outgoing call, the attendant may use this service feature to give dial tone to the station for completing his own call.

(53) *Pushbutton to rotary conversion.* The PBX can convert station pushbutton tones into rotary dial pulse signals as required by trunk groups or types.

(54) *Remote access to system.* The PBX can provide external callers access to system features and facilities on a programmed basis. Callers must dial a specified Listed Directory Number (LDN) which will be answered automatically by the system. After dialing an authorization code the caller will receive system dial tone, and may dial internally or externally over the system trunk facilities.

(55) *Remote maintenance.* Diagnostic and administrative functions may be performed from a remote location.

(56) *Restriction from outgoing calls.* Station users may be restricted from placing outgoing calls (Trunk Access) based on class of service.

(57) *Rotary dial calling.* This feature permits rotary station users to originate calls over rotary lines on a system basis.

(58) *Special dial tone.* Station users are provided with a distinctive tone when accessing certain system features.

(59) *Speed calling — group.* Selected groups can have access to group speed calling tables. Speed calling entries are performed at the station by the end user.

(60) *Speed calling — station.* Selected stations can have access to personal speed calling tables. Speed calling entries are performed at the station by the end user.

(61) *Speed calling — system.* The PBX provides access to common library of speed calling codes. The speed calling system list is entered and altered via the Maintenance and Administration Terminal (MAT).

(62) *Splitting.* This feature allows an attendant to consult privately with one of the parties while placing the other party on hold.

(63) *Station hunting — circular.* This service feature allows a call to be directed to an idle station line in a prearranged group when the called station is busy. The hunting sequence is unidirectional and station numbers can be in either consecutive non-consecutive order.

(64) *Station hunting — secretarial.* This service feature allows a station to be a common last choice in one or more hunting groups.

(65) *Station hunting — terminal.* This service feature allows a calling station which places a call to a busy station other than the pilot station of the hunting arrangement to receive busy tone and not proceed to the next idle station in the hunt group. If a call is placed to a busy station number which is the pilot in a hunt group, it will proceed to the next idle station in that hunt group.

(66) *Station to station calling.* This service feature permits a station user to directly dial another station within the same system without operator assistance.

67) *Three way calling.* This service feature allows a station user to add another station within the same PBX system to an existing connection for a three party conference. Subsequently, transfer is accomplished when the original party hangs up.

(68) *Tie line access.* The PBX can access tie lines on a trunk level basis.

(69) *Toll denial/toll diversion.* This feature permits station users to dial access to a local calling area but denies completion of toll calls or calls to the toll operator without the assistance of the attendant. This feature is provided for individual stations or on a route restriction basis. Restricted calls are routed to either attendant (diversion) or to intercept tone (denial) on a system basis.

(70) *Toll restriction — 3/6-digit.* Based on calling station class of service and in accordance with system data base programming, the PBX can allow orderly station access to specified area codes, exchange codes, or exchange codes within specific area codes over all or selected trunk types.

(71) *Universal sender.* This feature allows the dialed number to be sent out by use of a sender. The system will add or delete digits to meet the need of special trunk routes or for incoming or outgoing connections in which digit conversion is involved.

(72) *Wide area telephone service (WATS) access.* The PBX can access WATS circuits on a trunk level basis.

b. Optional features. Since these features can add considerable cost to the system, the possible uses in each application should be thoroughly investigated before being specified.

(1) *Least cost routing (LCR) — 3/6 digit.* The PBX can be equipped to select the most economical route available for each outgoing call, based on calling station, class of service, available facilities, time of day, and other conditions. The system can be programmed to perform dialed digit translation to comply with the requirements of the selected facility (WATS, FX, TIE, DDD). Station user dials a single access code for outgoing calls. Trunk queueing and speed calling features may be used in conjunction with LCR.

(2) *Maintenance and administration terminal (MAT).* The PBX is equipped with an intelligent terminal for system diagnostic and data base administration. MAT software is in English and operates from "MENU" driven table commands. No sophisticated computer language is required for routine system management.

(3) *Maintenance — printout.* The PBX can provide a hard copy of maintenance and system management data via the MAT.

(4) *Modem pooling.* For access by data terminals to analog network facilities, the PBX offers the ability to pool modem devices in a common access arrangement.

(5) *Music on hold.* The PBX can be equipped to provide music to held station/trunk party or a camped-on station.

(6) *Power failure transfer.* Calls normally terminated to the attendant positions are routed during a commercial power failure to predesignated single line telephones. This feature is utilized when reserve power is not equipped or when the battery reserve is depleted. Critical service, both incoming and outgoing to preassigned stations, is maintained by the feature.

(7) *Reserve power.* The system may be equipped with storage batteries to provide primary system operating current during a commercial power failure. Four hours of backup power should be available if a generator is available. If a generator is not available the batteries should provide eight hours of backup power. No loss of service should occur during transition to battery power.

(8) *Station message detail recording (SMDR) System — Electronic Industries Association (EIA) 232-D.* This feature provides a record of details of all outgoing station to trunk calls and incoming trunk to station calls. The details included are the calling station number, called number, access code, start time, elapsed time, month and day, and accounting code. This information may be used for analysis of central office trunk and tie trunk traffic for cost allocation, or billing purposes. SMDR information can be stored on a storage device such as a floppy disk on a personal computer.

(9) *Data switching.* This feature allows the station user to use the data communications equipment to transmit and receive data in a digital format at speeds up to 56 Kbps for synchronous data and 19.2 Kbps for asynchronous data.

3-4. Switch interface. The switch interfaces with the outside world and the system users through the use of trunks and lines, respectively. The outside world connection is normally referred to as the trunkside interface while the connection between the PBX and internal user is normally referred to as the lineside interface. In specifying the lineside and trunkside size of the PBX, the quantities as they relate to the equipped, wired, and system capacity should be identified. The definition of equipped for defines the quantity of lines or trunks to be originally installed at cutover. Wired for defines a capacity greater than the equipped-for size to allow for expansion without the addition of cabinets or equipment shelves. Expansion should only involve the addition of line or trunk cards. System capacity defines the line capacity to which the system should be capable of growing without replacement of the base system as installed at cutover.

a. Trunkside interface. The term "trunk" has acquired many meanings over the years; however, the most common definition is a channel between the equipment at two switching locations, whereas a channel connecting equipment to a human interface is normally referred to as a line. Through the use of trunks the PBX interfaces with the Public Switched Network (PSN) or with other DCO's or PBX's. Trunk circuit transmission can take either an analog or digital form. Where economically and technically available, digital formatted trunks are preferable and should be used unless otherwise directed. Trunks are classified according to their operation and application.

(1) Loop start trunks are energized when the PBX closes a current loop on an analog twisted pair of copper conductors. A current of 20 to 40 milliamps flows and signals the dial central office that a dial tone is desired to originate a call. In the reverse case when the central office is ringing the PBX, the PBX closes the loop when the call is answered to signal the switch to cease ringing. These trunks can be configured as one way or two way.

(2) Ground start trunks obtain dial tone by a momentary grounding of the ring side of the line. One advantage of a ground start trunk is that the PBX can instantly detect if the CO is ready. Some older CO's or PBX's require this type trunk because of potential problems with collision of signals or glare.

(3) Direct-inward-dialing (DID) trunks allow an incoming call to be automatically transferred, without attendant intervention, to the desired called party's extension and instrument. This operation is possible due to the capability of

the DID trunk in sending the three or four digit extension number of the called party along with the request for answer-back. DID operation requires specific trunk cards as well as reserving a group of 4 digit extension numbers prefixed by the central office code, usually termed the NNX, in the connecting central office. The requirement for DID trunks should be identified during the planning process.

(4) WATS trunks, while physically being the same type of circuit as other ground or loop start trunks, differ in the way the calls are billed. When used in an outgoing mode, WATS outbound, the trunks are defined in bands. Size concentric rating bands permit users to access progressively wider calling areas. Rate band No. 1 usually includes adjacent states surrounding the PBX's residing state. WATS inward, commonly referred to as 800 service, allows calling parties outside the PBX's local area to originate toll-free calls which will terminate on the PBX. A newer type of WATS service available from some long distance companies allows a circuit to serve the band the caller is calling. This allows better utilization of the circuits. The need for WATS lines should also be identified in the planning process.

(5) Foreign exchange (FX) trunks are similar to loop and ground start trunks except that the circuit is terminated and receives dial tone from a central office in a distant city or area. FX trunks are useful where there is a considerable amount of long distance calls being made or received from a distant city. A flat monthly rate depending upon location and distance is charged for FX trunk service. The closed end of an FX refers to the end connected to the PBX where the call can progress no further while the open end refers to the opposite end which originates the dial tone. The need for FX trunks should be identified during the planning process.

(6) Tie trunks, which can be used to connect the PBX to another PBX or the Post's central office switch, should employ 2 or 4 wires, E & M signaling, Multi-Frequency (MF) or Dial Pulse (DP) type trunks. In this manner all incoming and outgoing traffic utilizes the post's central office switch as the system interface. Proper coordination with the central office personnel is essential since routing tables must be entered into the post switch. Tie trunks are the primary choice when connecting to a direct digital interface operating at T-1 is typically available on most PBX's for tie trunk operation. Automatic Voice Network (AUTOVON) circuits from a host switch equipped for AUTOVON operation will utilize 2 wire, E & M, tie trunks.

b. Trunk configuration. Telephone users place calls at random throughout the 24 hours of the day, and the length of conversation varies from a few seconds to many minutes. However, the one hour in the day during which more calls are placed than any other hour is critical to the trunk configuration. This is known as the busy hour and it is the general practice to provide facilities on the basis of the traffic level in the busy hour. Also, the average duration of telephone calls of a particular type is fairly constant and this average, known as the holding time enters into the calculation of trunk requirements. The product of calls per hour and average holding time gives the total length of time that a particular trunk facility is in use or the "usage" during the hour. For example, if a trunk group carries 75 calls in the hour with an average holding time per call of 150 seconds, the usage on the group is 75 times 150 or 1,250 seconds. The generally accepted unit of measure for this item is CCS which equals 100 seconds. A total usage of 1,250 seconds would be expressed as 12.5 CCS. In the design of telecommunications systems the basic estimate of system size and capability usually is the number of lines to be served. To develop the amount of traffic handling capability to be provided by the system, the holding time per line is estimated. This generally is expressed in terms of hundred call seconds (CCS) per line. When the estimate is expressed in CCS per line, this figure, multiplied by the number of lines, gives the traffic volume or total unit calls which the switching equipment must handle. At any given instant, even during the busy hour, only a percentage of the instruments in a system will be used. Consequently, it is practical to provide trunks or paths for the calls on the basis of busy hour usage rather than on the basis of the number of instruments or lines connected. Enough trunks must be provided so that will encounter a dial tone delay or a paths-busy signal on only a small percentage of calls. Telephone traffic also varies from day to day and seasonally. In most systems, traffic is greater from Monday to Friday than over the weekend. Similarly, most systems experience a busy season during which traffic is greater than during other periods of the year. To provide a satisfactory grade of service, it is considered necessary to engineer for the busy season. To determine what is satisfactory, the concept of a grade of service (GOS) is used. GOS as an index number representing the probability that a call will be blocked or delayed during the busy hour. The grade of service index number is always prefixed with the letter P for probability, followed by a decimal value indicating the number of calls that will, on the average be blocked by a busy condition out of the total number of calls placed during the busy hour. For example, a grade of service of P.01 relates to a situation in which one of every 100 calls made during the busy hour will be blocked. P.01 is considered a reasonably good grade of service for PBX. Upon selecting GOS the traffic load must be determined. The two elements which determine the traffic load are the number of lines supported by the PBX, and the average holding time of each line per hour. The holding time can vary dramatically upon the type of usage. Light to heavy usage per line per busy hour ranges from 3 minutes (1.8 CCS) to 18 minutes (10.8 CCS). If little historical data is available, 8 CCS is typically used for the holding time for voice traffic, 36 for data traffic, and 36 for each attendant console. If a considerable amount of data traffic is anticipated, such as 10 percent of the PBX's traffic, a non-blocking PBX or one with data priority features should be required. The number of lines multiplied by the holding time per line results in the approximate amount of originating and terminating traffic during the busy hour. Upon estimation of the traffic volume and the desired GOS, refer to table 3-1 to determine the number of trunks required.

Examples of sizing the required trunk group or groups are shown below:

EXAMPLE

Given: 40 telephone users, all users require their own line, thus 40 lines needed, no holding time information available, GOS = P.01.

Then: 40 lines X 8 CCS/line = 320 CCS.

Use: Table 3-1 shows a requirement of 16 two-way trunks.

Given: 90 telephone users, all users require their own line. Since approximately 40 of the 90 personnel are involved with accepting incoming high priority customer related service calls, a GOS of P.005 is used for this group. Remaining 50 personnel represent typical usage.

Then: Use separate trunk group for customer service department, 40 lines times 20 CCS/line = 800 CCS. Table 3-1 shows a requirement of 34 trunks. These trunks will be configured in a one way-in mode. Two-way trunk traffic to accommodate all users outbound traffic plus incoming for 50 lines equates to (50 x 8 CCS) + (40 x 4 CCS/line) = 560 CCS. From Table 3-1, utilizing a P.01, 25 two-way trunks are shown to be required.

Table 3-1
Trunk Sizing Requirements
Traffic Expressed in CCS
Grade of Service

Number of Trunks	p.001	.002	.005	.01	.02	.05	.1
1	0	0	0	0	1	2	4
2	2	3	4	5	8	14	22
3	7	9	13	17	22	32	46
4	14	19	25	31	39	55	74
5	27	32	41	49	60	80,	104
6	41	48	58	69	82	107	135
7	57	65	78	90	106	135	168
8	74	83	98	113	131	163	202
9	92	103	120	136	156	193	236
10	111	123	143	161	183	224	270
11	131	145	166	186	210	255	306
12	152	167	190	212	238	286	341
13	174	190	215	238	266	318	377
14	196	213	240	265	295	350	413
15	219	237	266	292	324	383	449
16	242	261	292	320	354	415	486
17	266	286	318	347	384	449	523
18	290	311	345	376	414	482	560
19	314	337	372	404	444	515	597
20	339	363	399	433	474	549	634
21	364	388	427	462	505	583	671
22	389	415	455	491	536	617	709
23	415	441	483	521	567	651	747
24	441	468	511	551	599	685	784
25	467	495	540	580	630	630	720
26	493	523	568	611	662	754	860
27	520	550	598	641	693	788	898
28	546	578	627	671	725	823	936
29	573	606	656	702	757	858	974
30	600	634	685	732	789	893	1012
31	628	662	715	763	822	928	1050
32	655	690	744	794	854	963	1089
33	683	719	774	825	887	998	1127
34	711	747	804	856	919	1033	1165
35	739	776	834	887	951	1068	1203
36	767	805	864	918	984	1104	1242
37	795	834	895	950	1017	1139	1281
38	823	863	925	981	1050	1174	1319

c. Trunk medium. Depending upon the quantity of trunks required, the distance between the PBX and connecting office, and other factors, the trunk circuits can be arranged into one of five probable transmission media. These include (1) the use of copper cable pairs in a physical pair medium, (2) the use of T-Carrier multiplexing electronics with T-screened copper cable, (3) the use of multiplexing and fiber optic terminal equipment with fiber optic cable, (4) short haul infrared, and (5) 18 or 23 GHz microwave. As an aide in selecting the appropriate medium refer to table 3-2 for selection criteria information.

Table 3-2 Trunk medium selection guide

	Copper	T-Carrier	Fiber	Microwave	Infrared
Range	Load coils required after 18kft	Repeaters every 6000 ft.	Repeater-less for 25 miles	5 miles	2 miles-good conditions
Maximum Capacity	One channel per pair	24 channels per two pair	8064 channels per fiber pair	672 channels per system	672 channels per system
Typical Capacity	One channel per pair	24 channels per two pair	672 channels per fiber pair	96 channels per system	24 channels per system
Security	Low	Medium	High	Low	Low
Environmental Interference	None	None	None	Terrain heavy rain, snow	Terrain heavy rain, fog
Other Considerations	Expansion Difficult	Expansion Limited	High Initial Cost	FCC License Required	Worker may fear laser warnings

d. Lineside interface. Typically the largest number of interfaces in a telecommunication system occurs between the telephone instrument and the PBX. The PBX should be configured to provide one line or extension number identity to every instrument. In cases where the lineside interfaces are to be kept at an absolute minimum, two instruments may be bridged across one line, thus sharing the extension. This should only be done when usage on one of the bridged instruments is expected to be very low. The lineside interface or line circuit for an analog voice-only instrument typically consists of a 2-wire circuit with an impedance of 600 ohms. Depending upon the manufacturer, two to sixteen line circuits are located on a modular printed wiring circuit board. This board is typically called a line card. Another varying parameter between manufacturers is the line circuit loop resistance which limits the cable length between the interface and the instrument. Loop resistance values range from 400 to 1900 ohms (includes resistance of instrument) which corresponds to 1 to 6 miles using 24 American wire gauge (AWG) conductors. While single-building application loops should not present any problems, loops limits could be reached in a multiple building, single host configuration.

(1) *Lineside sizing.* In general, since the initial per line cost is usually substantially lower than additions, a PBX should be equipped for sufficient lines to meet the requirements for two to three years. The wired quantity should handle the expected growth for five to seven years and the system capacity should be specified to accommodate all future growth for the expected life of the PBX.

(2) *Telephone instruments.* The PBX telephone instrument is available in several different configurations depending upon the need of the user. Examples of telephone instruments are shown in figure 3-1.

(a) 2500 type set. Industry-standard single-line 2500 type Sets are used in applications requiring voice only usage. The set should be fully modular in construction and be equipped with a Dual Tone Multi-Frequency (DTMF) dialing pad.

(b) Tap set. The tap set, a variation of the 2500 type set, utilizes a button (usually located in the bottom right corner of the set) to access the system features normally activated by flashing the switchhook. Accidental disconnection is virtually eliminated when using a tap set. Tap sets should be the predominate choice for normal voice station applications.

(c) Electronic set. Users requiring more than one line and/or instant access to system features should be provided with electronic sets. The electronic set, available in several sizes (according to button quantities) are designed specifically for use with the PBX. The instrument not only provides traditional multi-line pickup service but also uses certain pushbuttons as feature buttons for ease in accessing system features. This set supersedes standard electrome-

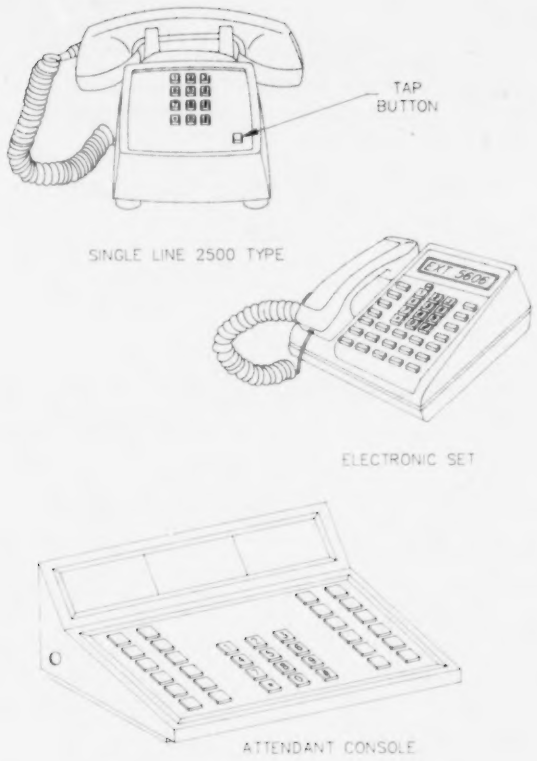

Figure 3-1. Typical telephone instruments.

chanical key equipment. Hands-free speakerphone operation can be integrated into the set or provided through a stand-alone unit.

(d) Attendant console. A call to a PBX is typically answered first by an operator or attendant utilizing an attendant console who extends the call to the line extension being called. The attendant console should accommodate a standard handset as well as a headset. Status of the system should be displayed through the use of indicators on the console which can show items such as trunks and line extensions in use. To accommodate quicker call processing and feature activation, major system feature buttons are located on the console.

(e) Data switching. Through the data capabilities of many of the voice/data PBX's, instrument users may perform simultaneous voice and data transmission or stand-alone data transmission at speeds up to 56 Kbps over 2 pair wiring without the use of modems. Data schemes currently supported include synchronous EIA 232-C, EIA 449-1, and CCITT V.35 data interfaces for speeds up to 56 Kbps and asynchronous RS-232C data interface for speed up to 19.2 Kbps. With voice/data PBX's, the Data Terminal Equipment (DTE) or Data Communication Equipment (DCE) can interface directly to the telephone instrument. The PBX should not be used as a data switch in applications where a data user will be on line more than 60 percent of a work period. These long sustained data calls can in effect load the switch down and reduce its call processing capability. To facilitate data transmission an integrated voice/data instrument is used. The instrument typically combines the user's analog voice conversation and digital data into one digital bit stream. At the PBX the voice and data are separated and routed to their respective destinations. If only data transmission is required, a data-only unit can be used. Since the transmission from the instrument to the PBX is in a digital format as opposed to analog, loop distances are typically much shorter. With the data capability of the PBX, dedicated hard-wired data systems can be eliminated by utilizing the PBX as a data switch. This configuration offers several advantages over a separate data system:

(1) Elimination of data cabling as data uses telephone cable for transmission medium.

(2) Maximizes utilization of host computer ports through the use of port contention whereby X + (n) DTE's contend for X ports.

(3) Allows for modem pooling which eliminates the need for dedicated modems for data communications with devices outside the system.

(4) Besides handling data in its usual bit-transparent mode, the PBX may also be used to provide format and protocol conversion for several of todays' computer systems.

3-5. Nonswitching equipment. Nonswitching equipment encompasses items such as inside cabling, distribution frames, and power systems. Figures 3-2, 3-3 and 3-4 depict the configuration of cabling and frames as described in this section.

a. Intra-building cable. Intra-building cable, usually called inside or premise cable, is divided into one of two categories depending upon its use.

(1) Station cable connects the telephone instrument to a distributing frame or punch-down block. A station cable should consist of 4 twisted plastic insulated pairs, 24 AWG, in a polyvinyl chloride (PVC) or plenum rated cable jacket. Plenum rated cable must be used in return air plenum environments. A plenum is defined as the continuous open space between the ceiling and the floor above .where ducts, wiring and return-air chambers for heat and air conditioning are located. Attention should also be paid to local code conditions concerning inside cabling.

(2) House cable connects a building entrance terminal (BET) to an intermediate distribution frame (IDF) or a main distribution frame (MDF) to an IDF. A house cable should be sized to accommodate the station cables connected to the IDF plus 25 percent growth. A house cable should be used in instances where a concentrated group, 25 or more, of telephone users' station cable run would exceed 200 feet. In multiple level buildings, house cables should be used to feed an IDF on each floor. In this multiple level application the house cable is typically termed riser cables. A typical riser diagram is shown in figure 3-5.

(3) Jack assemblies. To allow for interchangeable telephone instrument use and a neat and orderly interface, station cable will be terminated on a modular Universal Systems Ordering Code (USOC) RJ48C, 8 conductor jack assembly.

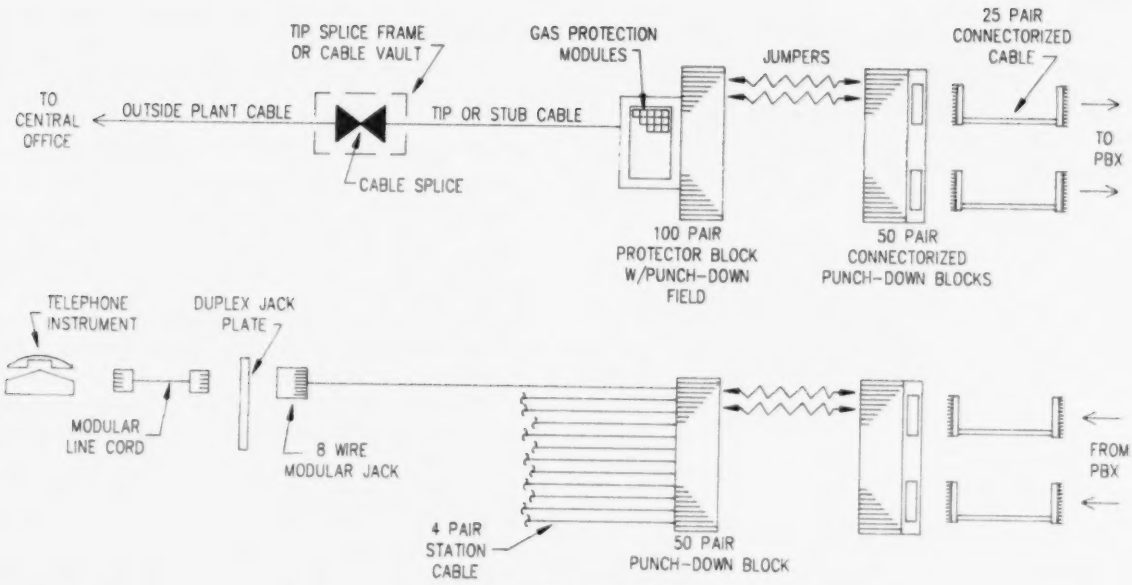

Figure 3-2. PBX system cabling

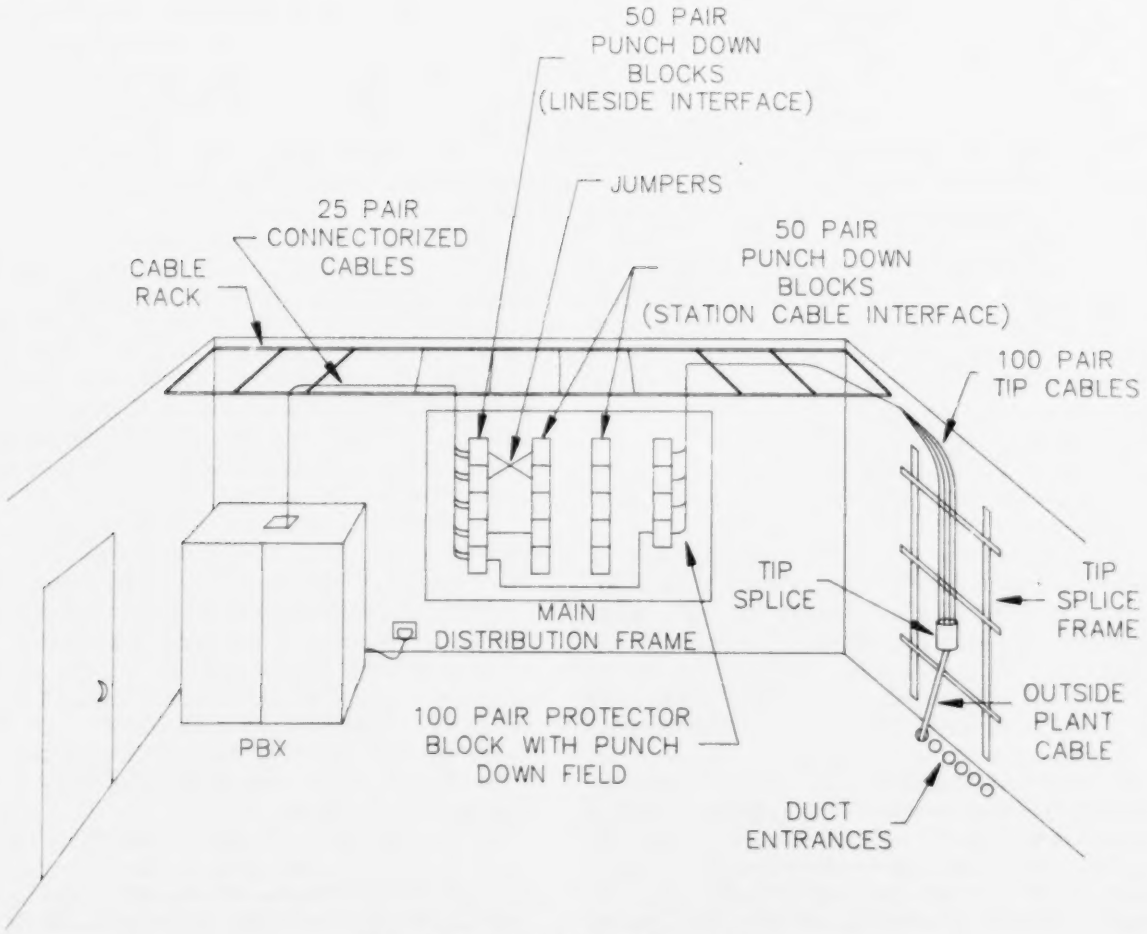

Figure 3-3. Inside distribution with tip splice frame

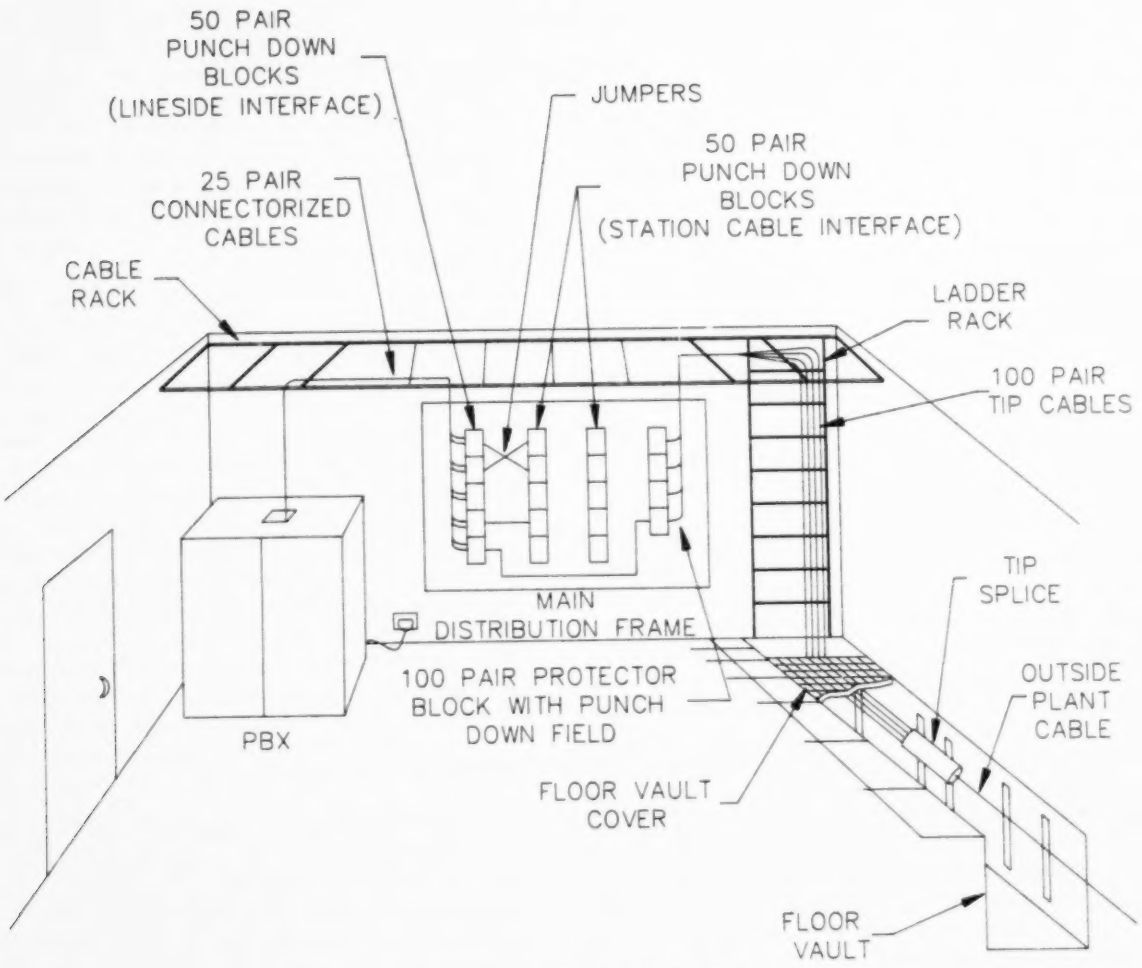

Figure 3-4. Inside distribution with floor vault

b. Distribution frames. Trunks or circuits entering a facility should never be terminated directly on the PBX or any other associated electronic equipment. A distribution frame should be used as the interface between any equipment and outside plant cable.

(1) *Main distribution frame (MDF).* A grounding source is required for all distribution frames. The distribution frame which is used as the interface between the outside plant cable providing the trunk circuits, and the PBX, is defined as the MDF. The MDF should provide three basic functions: (1) electrical protection, (2) cross-connection flexibility, and (3) test access. The MDF can take the form of a single-sided, floor mounted type frame for applications of over 200 trunks or lines, or a 3/4 inch plywood backboard mounted on a wall for smaller applications.

(a) Electrical protection. In terms of electrical protection, the MDF should be equipped with protector blocks, also called connector blocks, which house three-element gas tube protection modules to protect the equipment from voltage and current surges. Protector blocks are available for frame or backboard mounting applications. Protector blocks should come equipped with 25, 50, or 100 pair cable stubs, commonly called tip cables, for easy connection and splicing to outside plant cable.

(b) Cross-connect flexibility. Cross-connect flexibility is provided through the use of industry standard punch-down 66 type or wire-wrap terminal blocks equipped with 25-pair connectorized interfaces on the PBX side. With these blocks any cable reassignments or changes can be made easily at the MDF.

(c) Test access. Test access can be accomplished through the use of a test access field located on the connector blocks.

(2) *Building entrance terminal (BET).* In multiple building applications, a BET provides for the termination, protection, and distribution of inter-building cable entering a building adjacent to the PBX building. The BET should have the same means of protection as the MDF. Station cables inside the served building terminate on the BET through use of cable punch-down blocks. In an application where a 50 pair cable is serving a building the BET could be a one-piece unit

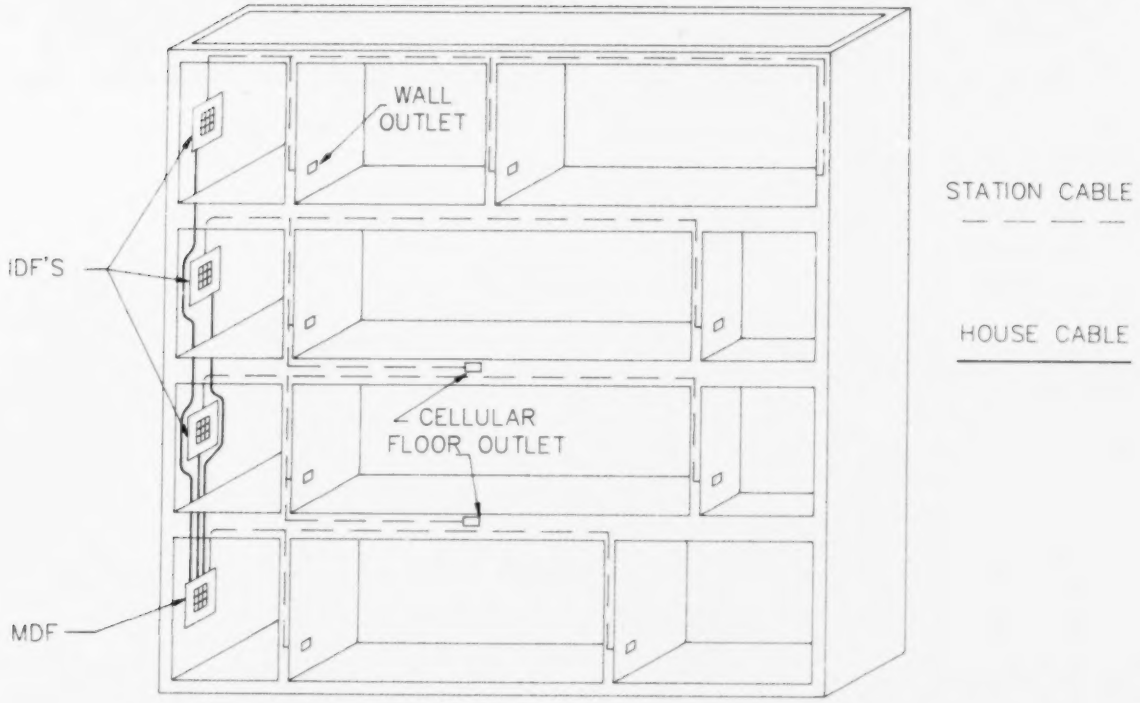

Figure 3-5. PBX house and station cabling

equipped with or without a 50 pair stub cable, gas protection modules,and a 50-pair punch- down field. If the outside plant cable extends more than 20' in an interior room a PVC stub cable should be spliced to the outside plant cable immediately upon entering the room. If less than 20', the outside plant cable may be terminated directly on the BET. This unit would be mounted on a wall or backboard near the building cable entrance. As inter-building cable is used in the out side, it must meet outside plant cable specifications and requirements.

(3) *Intermediate distribution frame (IDF).* In applications where a large number of users are located several hundred feet from the MDF, an IDF should be used to eliminate long and costly station cable runs. An appropriately sized house cable will interconnect the MDF and IDF. Individual station cable runs would then inter- connect the station user and the IDF. As the house cable stays within the confines of the building environment, no protection means is required for the IDF.

(4) *Tip splice frame (TSF).* To provide for the physical interface between the entering outside plant cable and the MDF, a TSF should be used. The purpose of the TSF is to provide a means to support the splice case enclosing the connection between the outside plant cable and the stub or tip cable of the protector block. The shields of the tip cable and outside plant cable should never be connected. Paragraph 5-2 discusses requirements for outside plant entrances. TSF's can take the physical form of a 3/4 inch sheet of plywood with rack arms to support the splice case(s) in small applications, or a steel frame above the cable duct entrances in large applications. Tip splices may also be accomplished in a floor vault in the communications room.

3-6. Environmental and facility requirements. Computerized PBX switching systems have significantly greater sensitivity to the environment than older mechanical systems. As with any computer, heat, high humidity, and noisy electrical power seriously degrade performance and cause unnecessary maintenance problems. More specifically, the designer must insure that the system is provided with:

a. Cable conduit. For new buildings the designer should work closely with the electrical engineer to ensure that all required conduits and raceways required for telecommunications and data cabling are being included in the design.

b. Adequate building space. The building space must be clean, secure, and dedicated to telecommunications equipment. Boiler rooms and other heat producing equipment rooms should not be considered. As the telecommunications system is the central nervous system of the facility, system security must be taken into consideration. The area should include secure, lockable doors. In cases of strategic operations, intrusion alarms should also be provided. The area should provide enough space to allow at least 24 inches of access clearance between all racks, bays and frames.

c. Electrical power. Based upon the type of PBX, either 120 Vac or minus 48 Vdc must be provided. This power

must be provided from isolated circuits that are not connected to motors. On systems larger than 1,000 lines, or critical systems that support strategic operations, the power supply system should be comprised of redundant rectifiers, a 48 volt string of batteries, and an inverter, if required. The rectifiers should be sized to provide sufficient amperage to fully recharge the batteries, in 24 hours, after they have experienced six hours of drain, plus simultaneously support the PBX's load.

d. Uninterruptible power systems (UPS). If required the designer should also determine the hours of required UPS reserve based upon the power requirements of the PBX. The UPS can take one of two forms. If the PBX requires 120 Vac, one piece units providing up to 15 KVA can be utilized. If the required reserve time can not be met with the rectifiers or battery chargers, a 48 volt string of batteries, and an inverter should be used. If the PBX requires only 48 Vdc, the dc based system without the inverter should be utilized. The reserve can range from 15 minutes to eight hours based upon the strategic importance of the installation and the likelihood that operations will continue during a power failure. Usually a four hour reserve is more than adequate for a PBX if a generator is available. Normally after this period the temperature of the area will interfere with normal switching system operations unless a backup system is also provided for the air conditioner. Batteries should be of the maintenance-free, sealed type.

e. Air conditioning. The area must be provided sufficient air conditioning capacity to maintain the area at approximately 74 degrees Fahrenheit and 50 percent relative humidity, with all equipment functioning. In strategic operations a backup air conditioner should be considered.

f. Fire protection. Facilities to house electronic switching equipment should be separated.from other occupancies by a minimum of 1-hour fire-rated walls. If a fire extinguisher system is required by local or national electrical and insurance codes, it should be of a type that will not damage electronic equipment. The fire protection system should be of a dry type, such as halon since damage to electronic equipment from water is usually extensive. Fire protection should be provided as required in MIL-HDBK-1008.

3-7. T-carrier systems. T-carrier systems may be utilized as the trunk medium between the PBX and the connecting switch. As mentioned previously the outside plant cable should be of the compartmental, screened type to facilitate the separation of the transmit and receive pairs. If the PBX is equipped with an integrated digital trunk interface, which multiplexes 24 voice channels into one 1.544 Mb/s digital bit stream, stand-alone channel banks can be eliminated. Regenerators or repeaters are required approximately every mile along the cable route and can be housed in above ground enclosures.

3-8. Fiber optic terminal equipment. Fiber optic (FO) terminal equipment may be used as the trunk medium between the PBX and central office switch or as the transmission medium linking a host PBX with a remote PBX as in a distributed architecture scheme. Most FO systems accept electrical DS-1 (T-1) signals and then provide an electrical to optical conversion process. While several PBX's currently provide DS-1 interface most PBX's will require the use of a T-1 channel bank which multiplexes 24 voice frequency channels into one DS-1. This DS-1 signal can then be interfaced to the FO system. FO systems are available which support only one DS-1 or multiplex up to 4 or 28 DS-1's together to produce a 6.3 Mb/s (T-2) or 45 Mb/s (T-3) bit stream. For a host/remote application, some PBX manufacturers can provide a proprietary fiber terminal integrated into the PBX equipment.

CHAPTER 4

OUTSIDE PLANT

4-1. Purpose. This chapter is intended as an overview and guide for the design of outside plant for PBX installations.

4-2. General. The criteria presented in this chapter is to be used to implement the overall plan or approach identified in the Design Analysis task which is described in chapter 2. In summary, during the Design Analysis task, it will be determined if distributed switching will be used and what type of outside plant approach will be used for each section of the outside plant network. Covered in this chapter are the major factors and criteria that should be used to implement the outside plant portion of the design. With many systems, the outside plant portion of the project will be minimal, as the project primarily involves the design of a PBX and associated inside wiring. With most PBX projects, the primary purpose of the outside plant is to provide feeder trunks between the PBX and the host CO, which can be a post DCO, or a local telephone company. Since the outside plant will not normally include distribution cable, this manual does not provide detailed coverage of the accessories required for distribution networks, such as pedestals, access terminal, and drops. However, even in a case such as this, it is likely that some outside plant engineering will be involved and, the outside plant link normally presents the greatest opportunity for signal interference and safety-related problems, especially if it is not properly designed. This is true because outside plant telecommunications facilities are commonly located in the vicinity of electrical power cables and other electrical systems that provide signal interference and possible power hazards and safety conflicts. The ANSI C2 must be followed rigidly.

4-3. Route selection. After the outside plant method of serving the various areas has been determined, a specific route must be developed. This task is extremely field-intensive and must be performed with a detailed knowledge of the site and terrain. The location of trees, rock formations, ditches, culverts, roads, buildings, other utilities, and soil conditions will determine the correct route and construction method and can only be adequately established by on site investigations and analysis. The outside plant design specialists should obtain all available site plans showing existing utilities and have access to, and knowledge of how to use, underground utility location equipment.

4-4. Cable sizing. Regardless of whether the cable is to be aerial, buried, or underground, it is almost always less expensive to provide the extra capacity initially than to add it at a later date. As labor constitutes a major portion of the cost of cable system construction, it is not unusual to be able to double the capacity while only increasing the total cost by 35 percent to 50 percent. This phenomenon is even more pronounced when installing smaller cables, such as 25 pair and 50 pair. To predict the pair requirements, an estimate of the expected growth rate must be available. As a guide, some typical rates for low, medium, and high growth in administrative operations are:

Type growth	*Annual rates*
Low	2.0% - 4.0%
Medium	4.1% - 7.0%
High	7.1% - 15.0%

In general, the objective should be to strike a balance between the cost of installing new cable at a later date and the cost of installing excess capacity initially. The concepts of Present Worth of Annual Charges (PWAC) from engineering economics must be used to exactly compute this breakeven point. The net result is that the designer should liberally allow for spare pairs in smaller cables since labor constitutes a larger portion of the total cost than the cable. As the cables become larger, the escalation factor should decrease, as the material cost constitutes a larger portion of the total cost. Table 4-1 provides an example of this concept, which can be used for a typical 5 percent growth rate. If a more detailed explanation is required for use in specific applications, see Section 231 of the REA Telephone Engineering and Construction Manual. For cables larger than 150 pairs, use the following equation to estimate the recommended cable size:

$$\text{Cable Size} = \frac{(\text{Initial Requirement})(1.0 + GR)^n}{1 - FF}$$

where GR = annual growth rate in percentage
n = planning period in years
FF = minimum percentage of cable pairs to be in reserve at the end of planning period, typically 5%.
note:round up to the next commercially available size

Example: Initial requirements = 112 pairs
GR = 4%
N = 10 years
FF = 5%

$$\text{Cable Size} = \frac{(112)(1.0 + .04)10}{1-.05} = 174 = 200 \text{ pair cable}$$

Table 4-1. Cable sizing for 5 percent growth rate.

FIVE YEAR CIRCUIT REQUIREMENTS	RECOMMENDED CABLE SIZE
4 pairs or less	12 pairs
5 to 7 pairs	18 pairs
8 to 10 pairs	25 pairs
11 to 30 pairs	50 pairs
31 to 50 pairs	75 pairs
51 to 80 pairs	100 pairs
81 to 136 pairs	150 pairs
136 pairs and above	Multiply by 1.11

4-5. Aerial cable plant. Aerial cable plant is more susceptible to physical and electrical damage than either underground or direct buried plant. It is much more difficult to design correctly, especially in a joint-use environment where electrical and communication cables are using the same pole line. Special care must be exercised to insure there is adequate clearance between communication and power cables in all weather conditions. In addition, proper clearance between cables and vehicular traffic must be insured. A minimum 18-foot clearance is usually required over all public roads and streets; however, if the Post is likely to have oversized equipment on the roads, it may be necessary to provide increased clearance.

a. Cable. Unless otherwise directed, air core, Plastic Insulated Conductor (PIC), copper, 24 AWG cable is to be used for all aerial circuits. Cable with compartmental screen shields is to be used for high frequency, T-1 carrier applications. This cable is often referred to as T-screen due to the fact that it is used to transmit T-carrier signals. REA specifications PE-22 in REA Bulletin 345-67 and PE-39 are in REA Bulletin 345-89 describe these cables in detail.

b. Strand. Normally it is best to attach the cable to the pole lines with a separate support strand whose strength is compatible with the size of cable to be installed. The cable will be attached by lashing it to the supporting strand, utilizing .049 inch lashing wire with a maximum 11 inch spiral wrap. Figure eight cable or self-support cable with an integral strand is not suitable for most applications due to problems associated with future expansion, such as adding a second cable. The separate support strand lends flexibility in that additional cables may be added at a later date, provided the strand and pole line support the weight and clearance is maintained. For most installations, 10M strand will be appropriate, if the span length between poles is less than 200 feet and the cable size is less than 200 pair of 24 AWG. However, the designer should always insure that the weather conditions and design requirements will not overload the strand or create unacceptable sag. There are a number of publications which can assist in the calculations, including REA Telephone Engineering and Construction Manual (TE & CM), Section 630. These and other publications rely upon the NESC concept of light, medium, or heavy loading districts to indicate the influence of weather. Figure 4-1 provides an example of an ANSI C2 storm loading district map, which is used to determine the classification which is appropriate for each particular area. Figure 4-2 and table 4-2 provide examples of the graphs and load data from TE & CM Section 630 that can be used to verify span lengths and sag. If longer spans and exceptional cable size and weight are required, it may be necessary to use 16M strand.

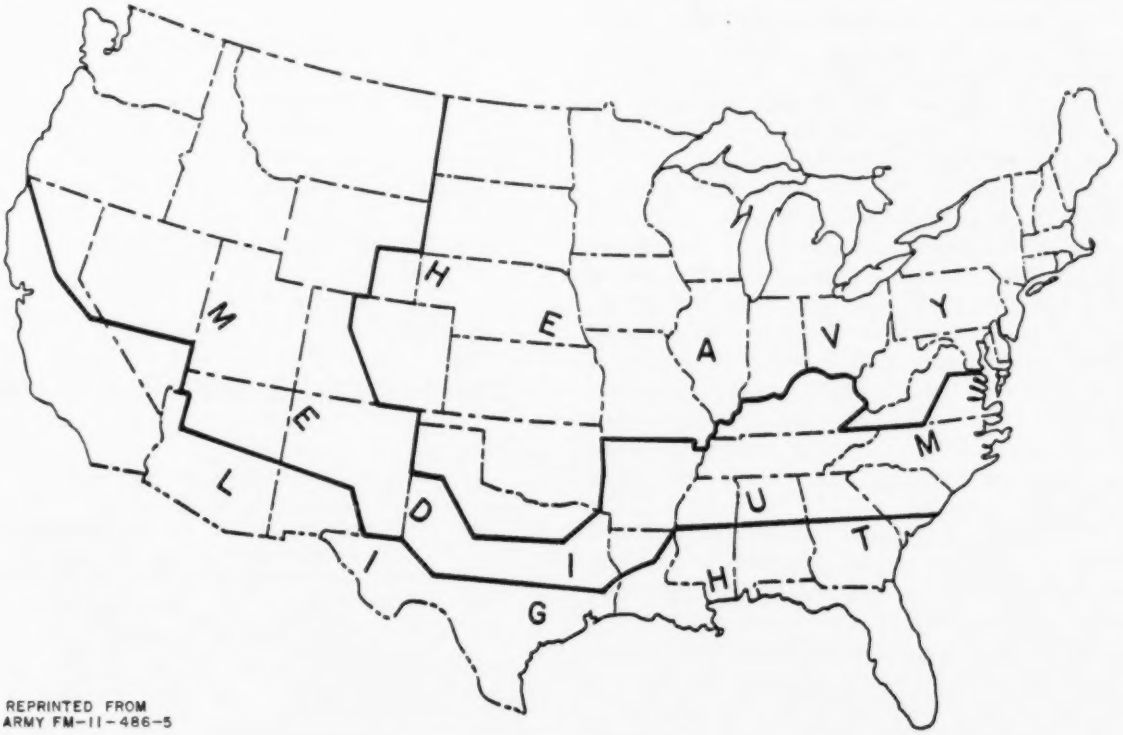

Figure 4-1. Storm loading map.

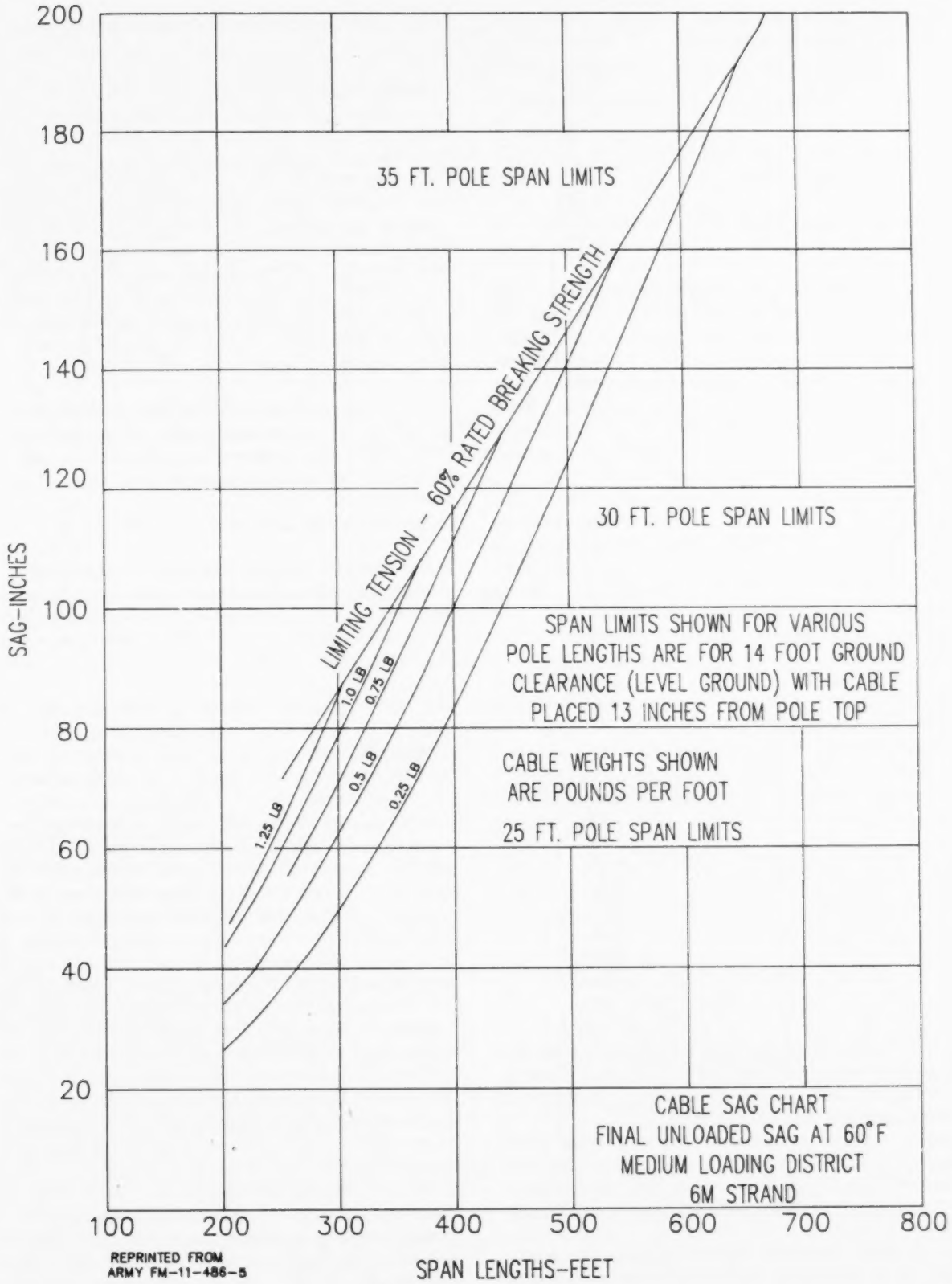

Figure 4-2. Cable sag chart

Table 4-2. Aerial cable weights in pounds per foot plastic sheathed & plastic insulated cable

Cable Pair Size	24 AWG	19 AWG
12	.12	.25
25	.18	.46
50	.31	.83
100	.53	1.45
150	.78	2.22
200	.98	2.75
300	1.40	3.89
400	1.77	4.95

c. Pole lines. The design of pole lines are similar to the design of bridges in that vertical loads, longitudinal loads, and transverse loads or moments must be considered. In summary, vertical loads include the weight of the various components; the longitudinal loads act in the direction of the line, and transverse loads act at a horizontal right angle to the line and typically result from wind. The weight of the components and the forces of nature must be taken into account. The basic convention is to convert all loads into equivalent loads two feet from the top and sum these loads to determine the required capacity. A pole is then chosen which will accommodate these loads. When computing weather-related forces, the same NESC convention of light, medium, and heavy storm loading districts is used that was described in the section on strand.

(1) *Pole selection.* Poles are classified according to their breaking strength with a rating system of 1 through 10; however, 8 is not used. The classification is not dependent on height or type of wood. It is based upon breaking strength with a load being placed 2 feet from the top of the pole. The breaking loads of the various classes are:

Class of Pole	*Breaking Load (LBS)*
1	4500
2	3700
3	3000
4	2400
5	1900
6	1500
7	1200
9	740
10	370

Converting the weights of cable accessories to loads and weather forces is beyond the scope of this manual. There are a number of handbooks and field manuals which provide graphs to assist in this process. However, with most installations a 30-foot class 5 pole will be sufficient for spans of 200 feet or less and cable sizes of 200 pair, 24 AWG cable and smaller. This pole should accommodate future growth requirements along the same route.

(2) *Setting.* The proper depth of pole setting is primarily a function of the height of the pole and the type of soil. In solid rock the settings are less and in swampy soil the settings are larger. For average soil the following settings are typical:

LENGTH OF POLE IN FEET	*DEPTH OF SETTING — AVERAGE SOIL IN FEET*
16	3.5
18	3.5
20	4.0
22	4.0
25	5.0
30	5.5
35	6.0
40	6.0
45	6.5

(3) *Guying and anchoring.* In general, guys and anchors are required whenever the aerial cable turns an angle or ends. The size and type of anchor and size guy wire required is a function of the force being exerted on the guy. This is determined by:

(a) The weight of the cable and accessories supported by pole;

(b) The interior angle of the line or the feet of pull;

(c) The angle between the pole and the guy wire. As the angle increases, the tension in the guy wire decreases. There are a number of options and methods available for guying and anchoring. Refer to TE & CM Section 650 for a detailed explanation of guy and anchor selection.

4-6. Underground systems. An Underground conduit provides the highest level of protection for communication cable and, if duct space is available, provides the easiest expansion capability for cables. When space is available in an existing underground system, it should always be used before considering new construction. The ducts should be cleaned out before new cable is installed; normally this will require rodding. Underground conduit runs are classified as either main or lateral runs and may contain either single bore or multiple bore ducts. New duct systems for support of new PBX installations will normally be limited to entrances to switches and under-road crossings. In rare cases a multiple building, single host PBX may require new main runs if the area is congested. For a detailed explanation of underground construction, refer to REA's Telephone Engineering and Construction Manual, Section 643 and TM 5-811-1. The requirements of the National Electric Safety Code should also be followed. Unless otherwise directed, filled, plastic insulated conductor, copper, underground 24 AWG cable should be used for all voice frequency circuits. Filled cable with a screen shield should be used for high frequency carrier circuits such as T-carrier. REA Bulletins 345-89, 345-67, and 345-13 describe these cables in detail. Before designing an underground system, it is imperative that all utilities be located and identified as discussed in paragraph 4-3. The next step is to determine the size of the duct system and the location of all new manholes.

a. *Size.* As the initial cost of construction is very high for any new duct system, an expansion capability of at least 100 percent should be provided in the initial design.

b. *Manholes.* Manholes should be planned at all lateral runs and at major angles of the main run. Geographic conditions will influence the placement of manholes; however, with large cables, reel lengths may be the limiting factor, as they are only available in increasing smaller lengths as the cables get larger. However, at an absolute minimum, manholes should be provided at 500 foot intervals. Sumps are to be provided in all manholes. If the water table is above the floor of the manhole, the sump should be sealed. If the water table is below the floor of the manhole, the sump should be equipped with a gravel type drain. Manhole covers should be 30" and their markings should be consistent with the utility marking used post-wide. In addition, the design should specify:

a numbering plan for all duct banks.

pull tape with footage scale for all ducts.

There are seven basic manhole configurations commonly in use which are shown in figure 4-3. Regardless of whether cast-in-place or precast manholes are used; construction will be simplified if the designer specifies one of these basic configurations.

(1) *Precast manholes.* Table 4-3 provides information on the precast manholes that are commonly available from most manufacturers.

(2) *Cast in place manholes.* These manholes must be completely described in the specifications because they are custom built. Their interior dimensions are critical since they must provide space for all racking and provide adequate access. The minimum headroom heights per type of manhole are as follows:

Type	*Headroom Height*
X	3' 5"
Y	4'
A	5' 5"
L	5' 5"
T	5' 5"
V	5' 5"
J	5' 5"

The roofs should be reinforced concrete and be sized according to the following chart.

Inside Width of Manholes	*Roof Thickness*
4'	7"
4.5'	7.5"

The floor of the manhole should be unreinforced concrete (6 inches) on firm soil and the walls should be four inches thick. New manhole inside measurements should be a minimum of 4 feet wide, 8 feet long, and 6 feet high.

c. *Conduit.* There are a number of different types of conduit and the best material for a specific project can only be determined after evaluating the cost and merits of each. Also, most conduit is encased in concrete or in earth (typically sand). The encasement of conduit in concrete is expensive and can complicate the construction process; this technique should only be used in special circumstances such as when the conduit will be exposed to heavy traffic or if the area is sandy and there is a concern that the ducts will float up during a period of high water. A minimum of 1/2 inch clearance should be allowed between the outside diameter of the cable and the inside diameter of the duct. Inner duct is to be used for small

Table 4-3. Typical precast manhole specifications.

USAGE	INTERIOR SIZE (FT) L X W X H	NUMBER OF SECTIONS	EXCAVATION SIZE (FT) L X W X D	MAIN CABLE CAPACITY	LATERAL KNOCK OUTS PER WALL
GENERAL PURPOSE INLINE	12 X 5 X 6.5	2	15 X 9 X 9.5	10	4
GENERAL PURPOSE INLINE	12 X 6 X 6.5	2	15 X 9 X 9.5	20	4
GENERAL PURPOSE INLINE	12 X 6 X 7.0	2	15 X 9 X 10.0	20	4
INLINE LARGE	12 X 6 X 10	2	15 X 9 X 13	28	4
J. L & T APPLICATIONS	12 X 5 X 6.5	2	15 X 8 X 9.5	10	2-SIDEWALL 4-SIDEWALL
J. L & T APPLICATIONS	12 X 6 X 6.5	2	15 X 9 X 9.5	20	2-SIDEWALL 4-SIDEWALL
J. L & T APPLICATIONS	12 X 6 X 7	2	15 X 10 X 10	20	4

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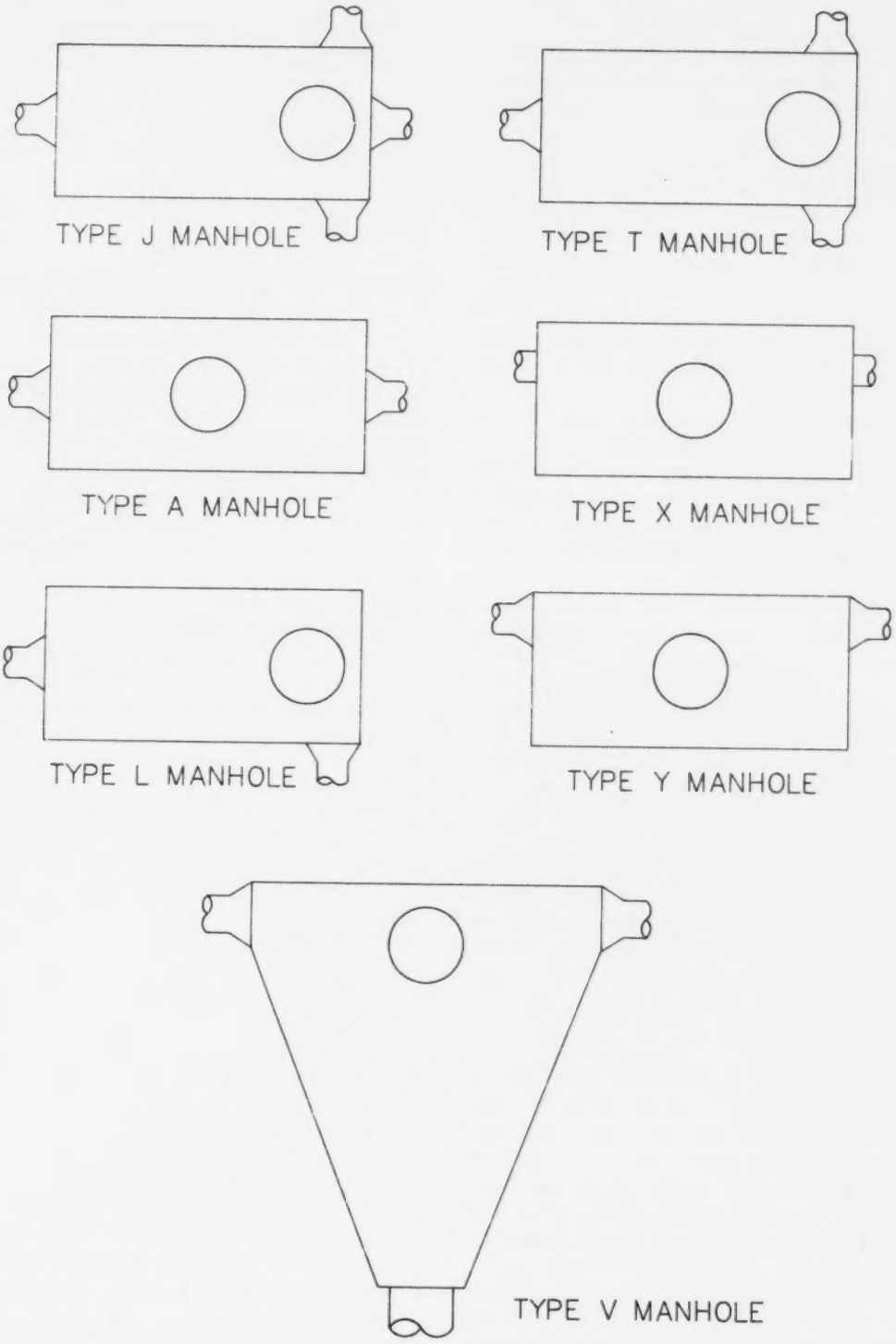


Figure 4-3 Typical manhole configurations.

copper cables and fiber optic cables in order to conserve space and provide protection. Four inner ducts are to be installed in any four inch duct which requires a single inner duct; otherwise, this duct may be unable to house additional future cables. The more commonly used types of conduit are:

(1) *Plastic conduit.* Most commonly used in PBX type underground installations, this conduit is available in Type I for concrete encasement and Type II for direct earth (typically sand) installation. Its semiflexibility permits gradual changes in shape without special fittings. This type conduit has a low coefficient of friction, thereby allowing longer runs. Jointing is accomplished with plastic sleeves which are cemented in place. Plastic spacers can be used to build formations and maintain the desired separation. Encasement in concrete is not normally necessary unless the conduit is going to be exposed to heavy loads, such as under roadways.

(2) *Steel pipe.* This single bore conduit is typically used only for special conditions or special applications where the other types of conduit are not practical. Common applications are under roads and railroads where trenching is not allowable and the conduit must be installed with a pipe pusher.

d. *Profile.* After the conduit and manholes are selected, profile drawings should be developed indicating the placement of the new ducts and the changes in elevation. Special care should be taken to insure that all ducts are designed to slope away from buildings to prevent the drainage of water into buildings.

e. *Underground cable racking.* Extreme care should be taken when racking cable and cable splices in manholes. A typical underground racking scheme is shown in figure 4-4.

4-7. Buried cable plant.

a. Route selection. The route selected for the buried cable should conform to the route established by the fundamental plan. Buried cable facilities require extensive detail with regard to route selection and right-of-way. The route selected should be accessible for construction and maintenance vehicles.

b. Cable selection. Cable used in direct buried applications should consist of 24 AWG jelly-filled, Plastic Insulated Conductors (PIC) with the required cable shield and an outer polyethylene jacket. Although the basic cable shield, such as aluminum, provides sufficient mechanical protection for routine laying operations, added protection is needed when damage from rocky terrain or rodents is expected. This added protection should be achieved by the use of internal steel tapes which give the cable extra physical protection against rock cuts and provide adequate protection against damage in rodent-infested areas.

c. Method of placement. The designer should be familiar with the characteristics and capabilities of the equipment used in the installation of buried cable plant so that he can identify which installation process should be used. Cable placement falls into three categories: plowing, trenching, and boring. Generally, plowing is the most economical means of placing buried cable; however, trenching becomes necessary when frequent obstructions are encountered. Boring is employed when constructions is required under rigid surfaces such as railroads, paved areas, and highways.

d. Depth of cover. In trenching or plowing applications, the depth measured from final grade to the bottom of the trench, or plow bottom, should be a minimum of 30 inches.

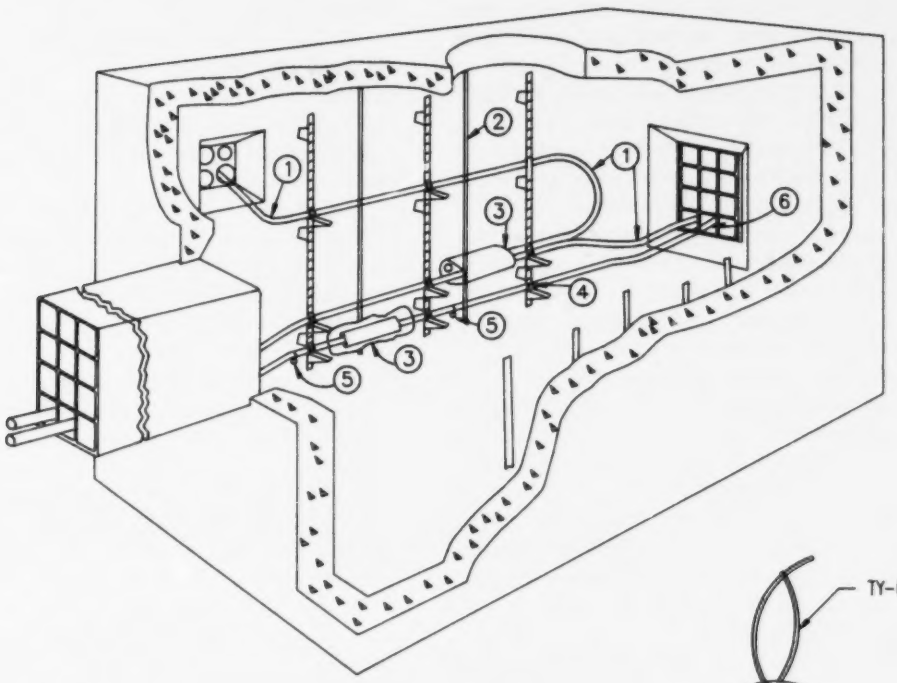
e. Splicing. Splicing of buried cable should be performed in above-ground closures. Mechanical type splicing connectors should be used.

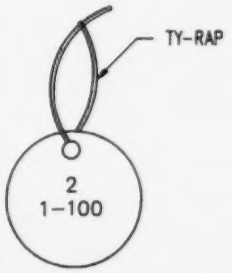
f. Closures. Cable closures used for cable splicing should be sized by the total pairs to be spliced in the closure. Consult manufacturer's specifications when selecting closure size.

4-8. Loading. PBX trunks which extend eighteen thousand feet or more from the post central office should be loaded for their entire length, regardless of gauge. The H-88 loading system should be used for all new construction. For additional design information refer to Rural Electrification Administration, Telephone Engineering and Construction Manual, Section 424.

4-9. Attenuation. Where the cable loss of PBX trunks exceeds 5 dB at 1000 Hertz, the designer should consult the post DCO personnel or local telephone company to advise of the requirements of electronic loop extenders. For additional design information refer to Rural Electrification Administration, Telephone Engineering and Construction Manual, Section 424.

4-10. Fiber optic cable. Applications involving a T1(1.544 Mb/s, 24 voice channels) span or multiple of T-1 such as T-2 and T-3, with electrical/optical terminal equipment should utilize multi-mode fiber cable for terminal equipment operating at or below 45 Mb/s. Single-mode cable should be used on higher rate systems. Attenuation for both multi- and single-mode fiber should be 0.5 dB/km or less at a transmission wavelength of 1310 nm. Bandwidth for multi-mode should be 1GHZ-km or greater. Dispersion for single-mode fiber should be 3.5 ps/nm-km or less. While fiber cables may employ similar shield and sheath makeup as copper cables, their most advantageous use is in aerial and direct applications where no metallic elements are used, thereby decreasing lightning attraction.

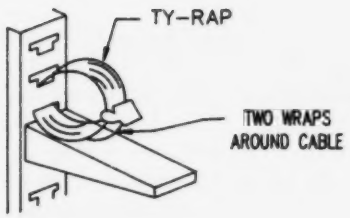




BRASS CABLE
TAG DETAIL

NOTES:

1. EXTREME CARE SHOULD BE USED IN THE FORMING OF CABLE(S) TO PREVENT KINKING. CABLES SHOULD NOT BE FORMED TO A RADIUS OF LESS THAN TEN TIMES THE DIAMETER OF THE CABLE.
2. SPLICE CASES SHOULD BE SUPPORTED BY THE CABLE RACKS TO PREVENT CABLE DAMAGE. IT IS SUGGESTED THAT A 1/2" OR 3/4" GALVANIZED IRON PIPE BE USED FOR THIS SUPPORT AND INSTALLED AS INDICATED ON THE DRAWING.
3. ALL SPLICE ENCLOSURES SHALL BE BONDED TOGETHER. THE METHOD OF BONDING WILL BE IN ACCORDANCE WITH INSTRUCTIONS ISSUED BY THE ENGINEER.
4. ALL CABLES SHALL BE SECURED TO THE CABLE RACKS WITH LASHED CABLE SUPPORTS.
5. BRASS CABLE TAGS SHOWING THE CABLE IDENTIFICATION AND PAIR COUNT SHOULD BE PLACED ON THE CABLE(S) ON BOTH SIDES OF SPLICES.
6. INSTALL DUCT SEALS OR PLUGS AS REQUIRED.



ATTACHMENT OF CABLE SUPPORT
TO MANHOLE CABLE RACK

Figure 4-4. Typical underground racking in manholes.

CHAPTER 5

GROUNDING

5-1. Grounding of inside plant. Electronic switching systems are susceptible to excessive induced and direct transient voltages and currents which may be introduced through incoming circuits, the building grounding system, or by electrostatic action. The inherent voltage sensitive characteristics of electronic switching systems are due primarily to the fragile nature of semiconductors and their fast transient response characteristics. Semiconductors typically have low breakdown voltage ratings and can be permanently damaged by excessive voltage spikes. Unless otherwise directed a single point grounding system for telecommunications gear should be used. The single point grounding system is designed to meet the protection requirements of most PBX equipment. No deviation should be made from the described method unless there are compelling reasons for change. The telecommunications grounding system described in this Section is one of three to four electrically connected subsystems which comprise a total facility ground system. Figure 5-1 shows the components and the layout of a single-point system.

a. Master ground bar. The Master Ground Bar (MGB) is the hub of the PBX single point grounding system and is used as a common point of connection for surge absorbers, surge conductors, and equipment grounds from isolated equipment areas. The MGB is a copper bar insulated from its support and is typically located either on a wall near the MDF, or on the cable vault wall. Surge absorbers provide a low resistance path to earth ground. The primary surge absorber is the PBX ground field. The ground resistance measured at the MGB should be five ohms or less.

b. PBX ground field. The outdoor portion of the ground conductors connecting the PBX ground field to the MGB should be buried a minimum 2.5 ft. below finished soil grade and enter the building through a nonmetallic conduit. The conductor should be placed in a straight line with no splices to reduce the impedance to fast-rising surges.

c. Cable entrance ground bar. Telephone cable shields should be bonded directly to a cable entrance ground bar (CEGB). The CEGB provides a common connection point for the purpose of terminating all incoming telephone cable shields. The copper bar, insulated from its support, should be located close to the cable entrance location. The CEGB should be connected by the most direct route to the MGB.

d. MDF ground bar. The MDF protector block ground straps should be bonded directly to a MDF ground bar (MDFGB). The MDFGB is a copper ground bar typically provided at the bottom of the MDF and is used as the connection point for the tip cable shields and MDF protector blocks. The MDFGB is connected by the most direct route to

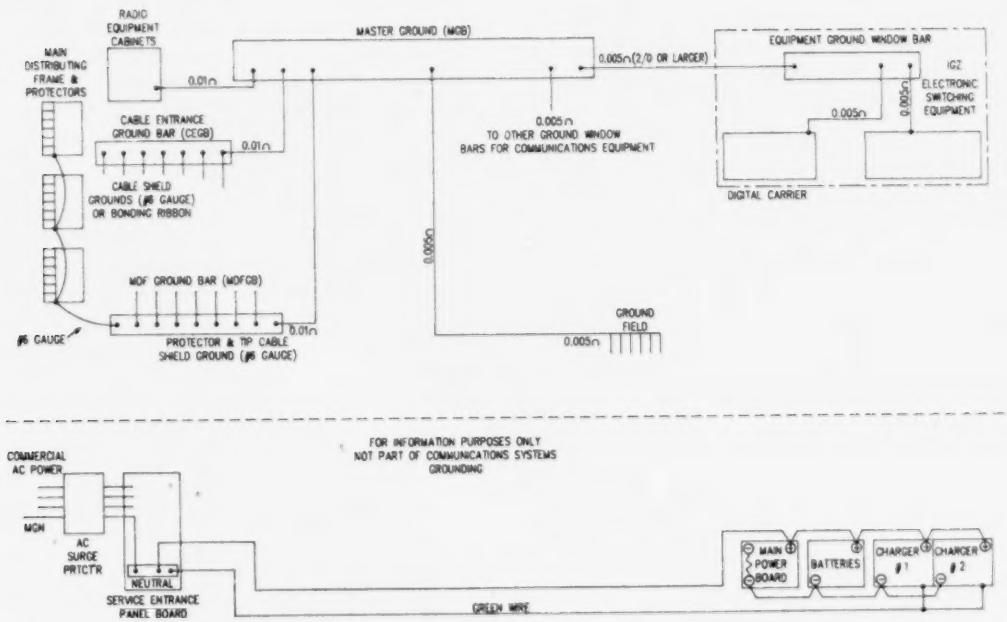


Figure 5-1. Single point grounding.

the MGB.

e. Isolated. Connections from equipment to the MGB are classified as isolated. Isolated equipment should include all sensitive electronic equipment such as the PBX and digital multiplexer equipment. This equipment should be located in a dedicated area where it is electrically insulated from external grounds except through a single ground connection. This ground connection is defined as the Equipment Ground Window Bar (EGWB) and is connected by the most direct route to the MGB. This area is referred to as an isolated ground zone (IGZ). All equipment grounds that originate inside a IGZ are terminated on the EGWB which should by physically located inside the IGZ and insulated from its support.

f. Ground conductor sizing, routing and terminating. The distance between the two points, to be connected and the resistance objective determines the appropriate sizing for all ground conductors. The point of reference for sizing all protective ground conductors except green wire conductors is the MGB. To determine the appropriate conductor size first establish the distance between the two points of connection via the desired route. Depending upon the resistance objective and the distance refer to table 5-1 to determine the appropriate conductor size.

(1) The smallest recommended conductor size is 6-gauge, except for the 14-gauge protective grounds at the MDF.

(2) The conductor between the MGB and EGWB should always be 2/0 gauge or larger. The total resistance of the conductor should be less than 0.005 ohms.

5-2. Grounding of outside plant. The outside plant portion of a telecommunications system is subject to disturbances from external sources of electrical energy. These sources include electric power supply circuits; natural phenomena, such as lightning and low energy static effects and electromagnetic interference (EMI) from other communications-electronics systems and equipment.

a. Underground. At intermediate manholes where the cable is pulled through without a sheath opening, bonds are not required. If the sheath has been opened,the shields of all such cables in each manhole should be bonded together by connecting a bonding wire or ribbon to each shield and to the manhole ground wire or ribbon. At all building entrances, telephone cable shields and conductors should be protected as described in paragraph 5-1c.

b. Buried.-cable. Buried cable is not normally as susceptible to damage from lightning surges as other categories of outside plant such as aerial. However, buried plant may be subjected to lightning damage by 1) direct strikes to the shield, 2) surges conducted to the buried plant from connecting facilities, such as power, which are struck by lightning, 3) induction from nearby strikes to ground and 4) by currents developed due to a rise in ground potential at stroke points near grounded station protectors or other grounded facilities. For protection from lightning, complete bonding of shields to maintain electrical continuity throughout the buried plant is required. At junction points the shields of cables should be bonded to the metallic shield of the main branch cable. The grounding connector provided in buried plant housings should be used to facilitate making these connections. Driven ground rods are not required at housings. At all building entrances, telephone cable shields and conductors should be protected as described in paragraph 5-1c.

c. Aerial. It is important that electrical continuity of aerial cable shields be maintained, and that such shields be bonded to any connecting buried or underground cable shields to provide a path to ground for lightning and power currents, and to provide an effective noise shield. Cable shields should be bonded to the support strand at frequent intervals to prevent arcing and to provide a low impedance path to ground for foreign currents. Four or more bonds per mile should be provided. Cable support strands should be grounded at dead ends and junction points.

Characteristics of Bare Copper Wire at 20° C/68° F											
CONDUCTOR SIZE		AWG #6		#4		#3		#2		#1	
dc RESISTANCE		.4110/kf	1.348/km	.2548/kf	.8478/km	.2050/kf	.6726/km	.1625/kf	.5331/km	.1289/kf	.4229/km
Obj. R	0.005Ω	12'	3m	19'	5m	24'	7m	30'	9m	38'	11m
	0.01Ω	24'	7m	38'	11m	48'	14m	61'	18m	77'	23m

Characteristics of Bare Copper Wire at 20° C/68° F											
CONDUCTOR SIZE		AWG 1/0		2/0		3/0		4/0		MCM 250	
dc RESISTANCE		.1022/kf	.3353/km	.0802/kf	.2631/km	.0636/kf	.2087/km	.0505/kf	.1657/km	.0440/kf	.1444/km
Obj. R	0.005Ω	48'	14m	62'	18m	78'	23m	99'	30m	113'	34m
	0.01Ω	97'	29m	124'	38m	157'	47m	198'	60m	227'	69m

Characteristics of Bare Copper Wire at 20° C/68° F											
CONDUCTOR SIZE		300		350		MCM 400		500		750	
dc RESISTANCE		.0367/kf	.1204/km	.0314/kf	.1030/km	.0275/kf	.0902/km	.0220/kf	.0722/km	.0147/kf	.0482/km
Obj. R	0.005Ω	136'	41m	159'	48m	181'	55m	227'	69m	340'	103m
	0.01Ω	272'	83m	318'	97m	363'	110m	454'	138m	680'	207m

Table 5-1. Sizing of ground conductors.

APPENDIX A

REFERENCES

Government Publications.

Department of Defense

MIL-HDBK 415	Design Handbook for Fiber Optic Communications Systems
MIL-HDBK 419	Grounding, Bounding, and Shielding for Electronic Equipments and Facilities
MIL-HDBK 420	Site Survey Handbcok for Communications Facilities
MIL-HDBK 1008	Fire Protection for Facilities Engineering, Design, and Construction

Department of theArmv, Air Force, and Navy

AFM 88-15	Air Force DesignManual Criteria and Standards for Air Force Construction
FM 11-486-5	Telecommunications Engineering, Outside Plant Telephone
TM 5-838-2	Medical Facilities Design - Army
TM 5-811-1	Electrical Design: Electrical Power Supply and Distribution

Federal Communications Commission

FCC Part 68	Connection of Terminal Equipment to the Telephone Network

Rural Electrification Administration (REA), United States Department of Agriculture,
Rural Electrification Administration, Washington, DC 20250

Bulletin 345-13	Specification forAerial and Underground Telephone Cable (PE-22)
Bulletin 345-67	Specification for Filled Telephone Cables (PE-39)
Bulletin 345-89	Specification for Filled Telephone Cable with Expanded Insulation (PE-89)
TE&CM Section 231	Design Techniques of Serving Area Value Engineering
TE&CM Section 424	Design of Two-Wire Subscriber Loop and PABX Trunk Plant
TE&CM Section 630	Design of Aerial Cable Plant
TE&CM Section 643	Underground Conduct and Manhole Design and Construction
TE&CM Section 650	Guys andAnchors on Wire and Cable Lines

Nongovernment Publications

American National Standards Institute (ANSI).
1430 Broadway, New York, NY 10018

ANSI C2	National Electrical Safety Code
ANSI Y 32.9	Graphic Symbols for Electrical Wiring and Layout Diagrams used inArchitecture and Building Construction

Electronic Industries Association (EIA),
Engineering Department,
2001 Eye Street, N.W.,
Washington, D.C. 20006

EIA 232-D	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
EIA 449-1	General Purpose 37-Position and 9-Position Interface for Data Circuit - Terminal Equipment Employing Serial Data Interchange

National Fire ProtectionAssociation (NFPA).
Publication Sales Department,
470 Atlantic Avenue, Boston,
Massachusetts 02210

NFPA 70	National Electrical Code

International Telegraphy and Telephone Consultative Committee (CCITT).
U.S. Department of Commerce, National Information Service,
5285 Port Royal Road, Springfield, VA 22161

Rec. 8.711	Mu-255 Law Encoding for Voice Information
CCITT V.35	Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment

GLOSSARY

Abbreviations

ac ..... alternating current
AFM ..... Air Force Manual
AM ..... amplitude modulation
amps ..... amperes
AUTODIN .. Automatic Digital Network
AUTOVON . Automatic Voice Network
BER ..... bit error ratio
BET ..... building entrance terminal
bps ..... bits per second
CEGB ..... Cable Entrance Ground Bar
cm ..... centimeter
CO ..... central office
CONUS ..... Continental United States
DID ..... direct inward dialing
dB ..... decibel
dc ..... direct current
DCA ..... Defense Communications Agency
DCO ..... Dial Central Office
DCS ..... Defense Communications System
DoD ..... Department of Defense
DoDISS ..... DoD Index of Specifications and Standards
EMI ..... electromagnetic interference
EMP ..... electromagnetic pulse
FM ..... Field Manual; frequency modulation
FO ..... fiber optic
ft ..... feet
FX ..... Foreign exchange
GHz ..... gigahertz
HF ..... high frequency
Hz ..... hertz
IDF ..... intermediate distribution frame
IF ..... intermediate frequency
in ..... inch
kVA ..... kilovolt-ampere
kW ..... kilowatt
kWh ..... kilowatt-hour
kbps ..... kilobits per second
m ..... meter
Mb/s ..... megabits per second
MDF ..... main distribution frame
MGB ..... Master Ground Bar
MHz ..... megahertz
NEC ..... National Electrical Code
NRZ ..... non-return-to-zero
ns ..... nanosecond
PBX ..... private branch exchange
RF ..... radio frequency
RFI ..... radio frequency interference
rms ..... root-mean-space
RZ ..... return-to-zero
SNR ..... signal-to-noise ratio
UPS ..... uninterruptible power supply
UHF ..... ultra high frequency
V ..... volt
VA ..... volt-ampere
Vac ..... volts alternating current
Vdc. ..... volts direct current
VHF ..... very high frequency

Terms

Analog

In communications, transmission employing variable and continuous waveforms to represent information value.

Attenuation

The loss of signal strength during transmission, designated by the Greek letter alpha. The energy in the transmitted signal is decreased by the transmission media as the signal progresses toward the receiving terminal.

ASCII

American Standard Code for Information Exchange. It's the most popular coding method used by computers.

AWG (American Wire Gauge)

A numerical table designating the cross section area of wire. Used as the principal standard for designating the size of wire in the United States. The larger the AWG number, the smaller the wire

Bandwidth

The carrying capacity of a communications device or channel; carrying capacity of a communications or channel; usually expressed in Hertz (analog) and more frequently in bps (digital).

BIT
An acronym for Binary Digit. A bit is the representation in binary code of one of two states of information 1 or 0. In electrical transmission this takes the form of either the presence ("1") or the absence ("0") of an electrical pulse.

Central Office
In telephony, the phone company the switching facility or center at which subscribers local loops terminate; handles a specific geographic area identified by the first three digits of the local telephone number.

Channel
In communications, physical or logical path following the transmission of information; the path connecting a data source and a receiver.

Circuit
Generally referring to a transmission medium connecting two or more electronic devices.

Circuit Switching
The process of establishing and maintaining a circuit between two or more users on demand, such that the users have exclusive use of the circuit until the connection is released.

Crosstalk
Unwanted transference of electrical energy from one transmission medium to another adjacent medium, generally in the voice-grade frequency range and a concern with the use of unshielded twisted pair wires.

Digital
Referring to communications procedures, techniques, and equipment where information is encoded as either binary "1" or "0"; the representation of information in discrete binary form

DP (Dial Pulse)
The pulses produced by the rotary dial associated with a telephone instrument to instruct the central office switching system, normally 10 pulses per second.

DTM (Dual-Tone Multi-Frequency)
The tone pairs .produced by touch-type pushbutton key pad used with a telephone, instead of a dial pulse, for communicating with the central office switching system.

Electronic Key Telephone Systems
A key system in which the electromechanical relay controls are replaced by electronic devices, sometimes located within the telephone instrument. Heavy multiple cabling is reduced to four or six pair wiring to each telephone instrument.

Fiber Optic
Transmission technology using glass or plastic fibers with pulses of light energy used to convey information.

Frequency
The number of repetitions per unit of time of a complete waveform, the number of complete cycles per unit of time, usually expressed in Hertz (Hz).

Frequency Division Multiplexing
Technique for sharing a transmission channel wherein carrier signals of different frequencies are transmitted simultaneously.

Full Duplex
Operation of a data communications circuit where transmissions are in both directions at the same time.

Hertz (Hz)
Measurement that distinguishes electromagnetic waveform energy; the number of cycles, or complete waves, that pass a reference point per second; measurement of frequency where one Hertz equals one cycle per second.

Interface
A physical point of connection between two devices

LED (Light Emitting Diode)
As with a laser, this is a device that accepts electrical signals and converts the energy to an optical signal; light source for fiber optic transmission.

Line
Usually refers to the connection between the PBX and station equipment, or any human interface.

Medium
A material substance that is used for the propagation of signals, such as fiber optic, cable, wire, etc.

MODEM: Modulator/demodulator
Electronic device that enables digital data to be sent over analog transmission facilities.

Multiplexed Channel
A communications channel capable of servicing a number of devices, or users, at a time, i.e., T-1 channel.

Multiplexer
A device that performs multiplexing; a device that allows two or more users to share a common transmission medium; used in pairs, one at each end of the communications channel.

Network
A group of switches, terminal equipment, software and peripheral hardware interconnected with communications channels that are used to establish connections among network users.

Noises
Unwanted signal disturbance in a communications line, due to electromagnetic interference, causing random variations in information signal.

Nonblocking
Describing a switch where a through traffic path always exists for each attached station; generically, a switch or switching environment designed never to experience a busy condition.

Off-hook
In telephony, condition indicating the active status of a subscriber's telephone circuit, signals a Central Office that a

user requires service.

Optical Fiber or Fiber Optic Cable
A fiber that is used to transmit laser or LED-generated light signals.

PBX (Private Branch Exchange)
A general purpose switch which primarily establishes connections between individual users and the public switched telephone network.

Port
A point of access into a computer, a network or other electronic devices; the physical or electrical interface through which one gains access.

Public Network
Generally, a network established and operated by communications common carriers or telecommunications companies for the provision of circuit-switched, packet-switched and leased line circuits to the public.

Shielding
Protective enclosures surrounding a transmission medium, such as coaxial cable, designed to minimize electromagnetic energy leakage.

Terminal
A device capable of sending and receiving information over a communications line network.

T-1
Term for a digital carrier mode; operating at a 1.544 megabit channel per second rate usually encompassing 24 voice channels.

T-carrier
A digitally multiplexed transmission system operating at a T-1 rate.

Tie line
A leased or private dedicated circuit provided by the local telephone company or common carriers linking two or more voice switching systems.

Tip
As in tip cable or stub cable; the preconnected cable attached and terminated on a building entrance terminal or protector block.

Trunk
Usually refers to the connection between a PBX and the telephone company central office. A connection between two pieces of switching equipment.

Two-Wire Circuit
Usually a telephone circuit consisting of two insulated electrical conductors, typical of most local loops.